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ABSTRACT

Reported is a research project which investigated whether junior high students in the Ithaca, New York, area can acquire and use the "concept mapping" and "Gowin's 'V' mapping" strategies to facilitate meaningful learning. Concept mapping involves the identification, hierarchical organization, and graphic depiction of relationships among concepts in a body of study material. These procedures are consistent with Ausubel's theory of meaningful learning. The second learning strategy involves recognizing that all knowledge in the sciences is constructed by using records and record transforming procedures which are guided by the concepts, principles and theories that people employ. Gowin's "V" is a heuristic device that students use to graphically illustrate the interplay between the methodological and conceptual elements of each episode of knowledge-making, such as a laboratory investigation. Although many project activities centered on implementation of the two learning strategies, the positive cognitive and affective data lend support to the effectiveness of this "learning how to learn" project. Included in the appendix are the teacher's handbook and samples of student-constructed concept maps and "V" maps. (Author/WB)

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THE USE OF CONCEPT MAPPING AND GOWIN'S "V" MAPPING INSTRUCTIONAL STRATEGIES IN JUNIOR HIGH SCHOOL SCIENCE

THE CORNELL UNIVERSITY "LEARNING HOW TO LEARN" PROJECT

Supported in part by grants from the National Science Foundation
(SED 78-16762) and Shell Companies Foundation

Opinions expressed and conclusions reached represent the views of the Project Director and staff and are not necessarily those of the National Science Foundation or Shell Companies Foundation.

SE 034 583

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

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	4. Award Period From 9/15/78 To 12/31/80	5. Cumulative Award Amount $126,600

6. Project Title
Strategies for Learning Emphasizing the Nature and Role of Concepts

PART II–SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

This study was centered around the question, "can junior high school science students acquire and use the learning strategies of 'concept mapping' and 'Gowin's 'V' mapping' to facilitate meaningful learning?"

Concept mapping involves identification concepts in a body of study material and organization of these concepts into a hierarchical arrangement from the most general, most inclusive concept to the least general, most specific concept. These procedures are consistent with Ausubel's theory of meaningful learning. Furthermore, concepts in the map are related to each other by "connecting lines" in the concept map that define propositions or specific relationships between concepts and the acquisition of relationships between concepts is the key element in meaningful learning (Ausubel, 1968, 1978).

A second "learning strategy" is the recognition that all knowledge in sciences is constructed by using concepts and record making or record transforming procedures, guided by the concepts, principles and theories we employ. Gowin's "V" is a simple heuristic device to show this interrelationships between, on the one hand, concepts, principles and theories, and on the other hand, observational or record making procedures, record transforming procedures (e.g. graphs, tables or statistical computations) and consequent "knowledge claims."

Data show that both high and low ability seventh and eighth grade students can acquire adequate skill in the use of the strategies, in conjunction with ordinary junior high school science programs, and that there is an association between skill in using the strategies and positive attitudes toward science and success in new problem solving.

PART III–TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
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b. Publication Citations				X	4-81
c. Data on Scientific Collaborators		X			
d. Information on Inventions	X				
e. Technical Description of Project and Results	▨	X			
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ABSTRACT

This study was centered around the question, "can junior high school science students acquire and use the learning strategies of 'concept mapping' and 'Gowin's 'V' mapping' to facilitate meaningful learning?"

Concept mapping involves the identification of concepts in a body of study material and the organization of those concepts into a hierarchical arrangement from the most general, most inclusive concept to the least general, most specific concept. These procedures are consistent with Ausubel's theory of meaningful learning. Furthermore, concepts in the map relate to each other by "connecting lines" that define propositions or specific relationships between concepts, for example that "Arthropods have jointed appendages." We define concepts as "regularities in events or objects designated by a sign or symbol," and in our example "Arthropods" and "jointed appendages" represent two concepts. Propositions, in turn, are relationships between concepts (as in our example) and the acquisition of relationships between concepts is the key element in meaningful learning. (Ausubel, 1968, 1978).

A second "learning strategy" or "meta-learning" activity (i.e., learning about learning) is the recognition that all knowledge in the sciences is constructed about events and objects by using concepts and record making or record transforming procedures, guided by the concepts, principles, and theories we employ. Gowin's "V" is a simple heuristic device to show this interrelationship between, on one hand, concepts, principles, and theories, and on the other hand, observational or record making procedures, record transforming procedures (e.g. graphs, tables, statistical computations), and consequent "knowledge claims." Students learn to recongize that our "knowledge claims" in science are dependent on the concepts and theories that guide our inquiry, and also on our record making and record transforming procedures.

The study was conducted with seventh and eighth grade science students in the Ithaca, New York area. Data show that both high and low ability seventh and eighth grade students (as measured by standardized achievement tests) can acquire adequate skill in the use of the strategies in conjunction with ordinary junior high school science programs, and that there is an association between skill in using the strategies and positive attitudes toward science and success in new problem solving. Although this research is in the category of a "preliminary investigation," with much of the project activities centered on procedural problems for classroom instruction in the strategies (including preparation of a "Teachers Handbook"), the cognitive and affective achievement data are positive and favor further research and implementation of the "learning how to learn" strategies.

ACKNOWLEDGEMENTS

The staff of the "Learning How to Learn" Project would like to express their appreciation to the many people who have given their time and energy so that this project and the final report could come about.

First, to the National Science Foundation that provided principal funding for the project through the years 1978-1980, and also to the Shell Companies Foundation.

To the teachers, Sarah DeFranco of the Trumansburg Middle School, Mary Bente and Jay Decatur of the African Road School in Vestal, Doug Larison of the Lansing Middle School, and Denny Wright of the Homer Junior High School. A special thanks goes to Chuck Shrnka of the Boynton Junior High School in Ithaca for some initial trials with our ideas. Also, to Ron Armstrong of South Glen Falls, New York, who quite independently worked with these strategies and graciously shared those experiences and suggestions with us. All these teachers have expended great effort to try these ideas in their classes, and have provided honest and clear criticism of the program. Given all the constraints that classroom teachers work under, it is remarkable that they tolerated all the visits, revisions, re-writes, and re-definitions with smiles and understanding.

To the students of Trumansburg, Vestal, Lansing, Homer, and Ithaca for all their work on our behalf. Anyone involved with education knows that the student is our most severe critic. We hope that we have given them as much as they have helped us.

To the administrators, Joseph Meskill in Trumansburg, Thomas Jones in Lansing, Albert Guzzi and Jack Higham in Vestal, and Harley Albro in Homer. Their interest and support are much appreciated.

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To our consultants at Cornell, Professors D. Bob Gowin, Emil Haller, Donald Holcomb, Jason Millman, and Dom Paolillo. Their constant pressing for the right questions to be asked forced us finally to ask them. To Professors Robert Howe (Ohio State), Leo Klopfer and Audrey Champagne (Univeristy of Pittsburg), Jane Kahle (Purdue University), and Jill Larkin (Carnegie Mellon University) for all their help and useful suggestions.

Several drafts of this final report were prepared by Gerry Johansen who also coordinated staff efforts during the 1979-1980 school year.

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I. ORIGIN AND CONCEPTION OF THE PROJECT

During the 1950's and early 1960's, Novak and his students conducted research on factors influencing problem solving. This early work was done employing a cybernetic model (Weiner, 1948; Estes, 1950 ; Novak, 1965) that emphasized the distinction between storage of information and processing of information. By 1965, our research group became familiar with David Ausubel's (1963) cognitive learning theory that emphasized the central role that concepts* play in the acquisition and use of knowledge, and Ausubel's theory became the psychological foundation for our research from this time foward (Novak, 1966, 1977a).

Another factor contributing importantly to the conception of the project were changes occuring in views on the history and nature of science. Conant (1947) and later his protege Kuhn (1962) emphasized that inquiry in science is guided (and sometimes constrained) by the "conceptual schemes" or "paradigms" scientists invent. This epistemological shift away from Baconian-Pearsonian tradition that dominated philosophy of science for 300 years led to an emphasis on the mutable, evolving nature of scientific concepts, best characterized by Toulmin (1972). This epistemological shift, from a view of science as an enterprise in search of "laws" of nature to an enterprise seen as much more served by evolving conceptual schemes or explanatory models, provides a view of knowledge complementary to a psychology of learning centering on the acquisition and use of concepts.

Over the past two decades, our research work and curriculum development activities led in the direction that suggested that students can be aided in learning not only through better specification of learning objectives and organization of subject matter, but also through explicit guidance to students in learning strategies. Although much of our research and related work of Reif (1976) and his colleagues at Berkeley was conducted with college students, our research with children (Hibbard and Novak, 1975 ; Nussbaum and Novak, 1976) and the work of Karplus (1979) and others suggested that junior high students should be successful in acquiring specific strategies in learning to aid them in learning and understanding science.

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*Although many variations exist in the definition of "concept," we have defined it as a regularity in events or objects designated by a sign or symbol.

From our research program and theory development, two specific pedagogical techniques emerged as useful learning strategies: concept mapping (see Figure I.1) provides a tool for aiding students to understand the salient role that concepts play in learning and interpreations of events or objects; Gowin's epistemological "V" (see Figure I.2) to illustrate the interplay between conceptual and procedural elements involved in knowledge production. These two pedagogical techniques are derivatives from learning and curriculum theory guiding our work, and from an epistemology consistent with contemporary views of the process of knowledge production in any rational enterprise. The primary purpose of the research reported here was to address the question:

> *CAN SEVENTH AND/OR EIGHTH GRADE SCIENCE STUDENTS LEARN TO USE CONCEPT MAPPING AND "V" MAPPING STRATEGIES IN CONJUNCTION WITH EXISTING SCIENCE PROGRAMS?*

Secondary, but also important, questions were:

> *WILL STUDENT'S ACQUISITION OF SCIENCE KNOWLEDGE AND PROBLEM SOLVING PERFORMANCE CHANGE AS A RESULT OF THE STRATEGIES?*
>
> *WILL STUDENTS SHIFT TOWARD A MORE POSITIVE ATTITUDE ABOUT SCIENCE?*
>
> *CAN CLASSROOM TEACHERS BE TAUGHT TO INSTRUCT PUPILS IN THE PROPER USE OF THESE STRATEGIES?*

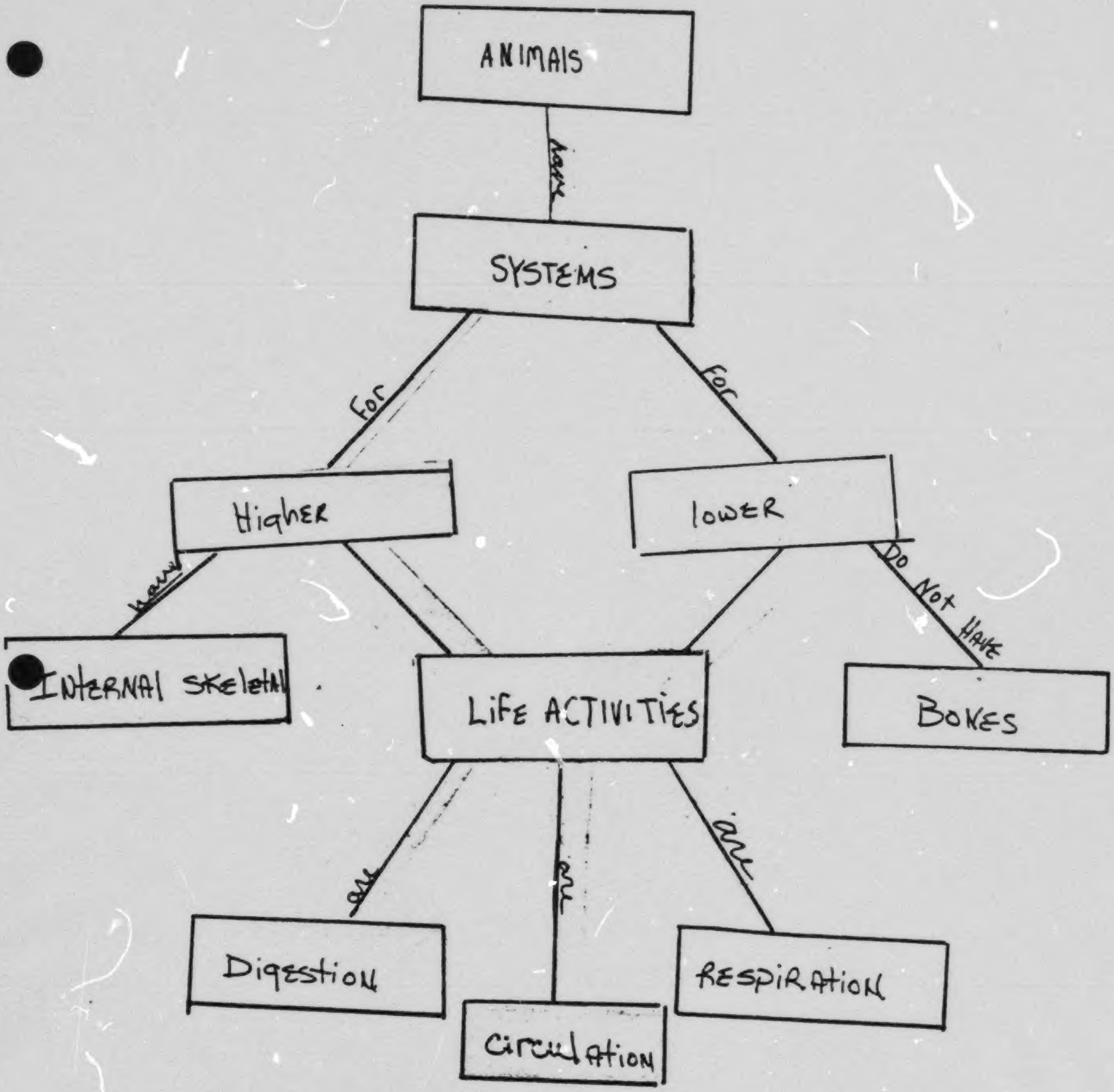

ANIMAlS
have
SYSTEMS
for
for
Higher
lower
have
Do Not Have
INternal skeletal
LIFE ACTIVITIES
BONES
are
are
are
Digestion
Circulation
Respiration

Figure I.1. Concept Map prepared by student #065 during preliminary clinical interviews (October/November, 1979).

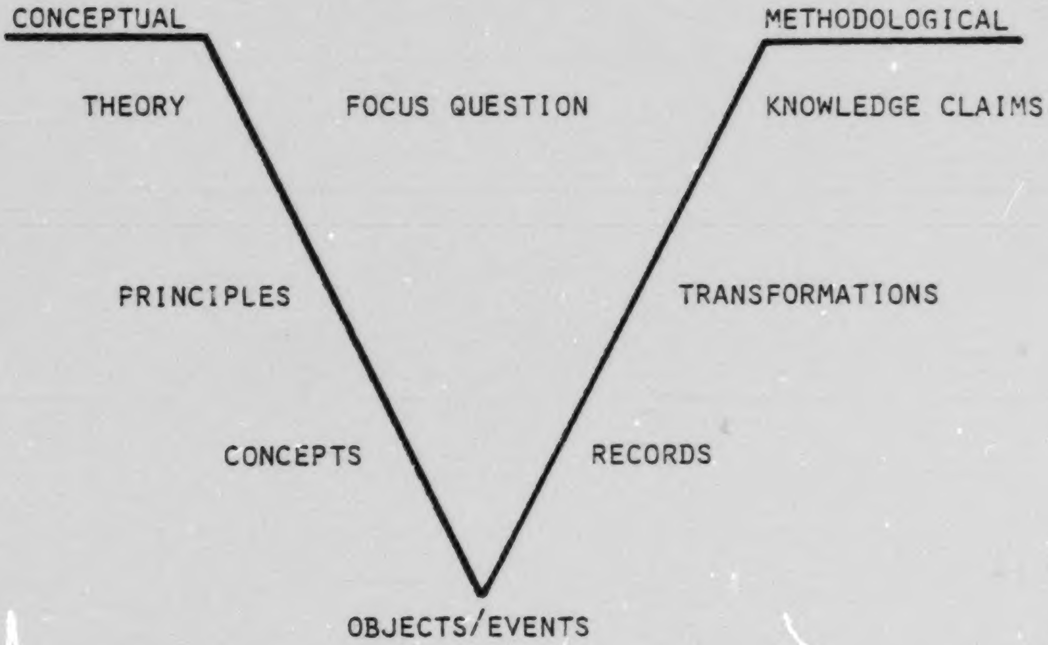

CONCEPTUAL
METHODOLOGICAL
THEORY
FOCUS QUESTION
KNOWLEDGE CLAIMS
PRINCIPLES
TRANSFORMATIONS
CONCEPTS
RECORDS
OBJECTS/EVENTS

Figure I.2. Gowin's Epistemolcgical "V" (in press) used with seventh and eighth grade students as a heuristic to help in understanding how knowledge is produced in the sciences.

In the limited scope of this research (projected initially over one calendar year) we could not expect to obtain more than tentative answers to the secondary questions mentioned.

It was quickly realized by the staff and the consultants of the "Learning How to Learn" Project that this research was a true inquiry. As such, we had to expect to wrestle with theoretical issues, create evaluation instruments that reflected the theoretical bases of the project, find ways to best implement these strategies in the classrooms, and work within the framework that governs public schools. This spirit of inquiry is reflected in the sections of the report that follow, not only in the descriptions and examinations of what worked in the research, but also with the descriptions of what did not work. In some respects, this latter concern is more important since it provides other researchers with standards of caution to not pursue what has already been shown to be ineffective.

Initially, our plan was to have research project staff members teach the learning strategies, using the subject matter ordinarily presented in the classroom. However, the teachers who chose to work with us were intrigued by the strategies and preferred to incorporate them into their own instruction. This, of course, was more desirable, not only because it released staff time for evaluation and other duties, but also because it showed promise for eventual wide-scale dissemination of the learning strategies.

We were hopeful that some explicit instruction in learning psychology, especially on the role that concepts play in meaningful learning, would introduce and permeate instruction in the program. While all teachers were receptive to introductory materials on the psychology of learning (see Appendix I, section II), there was an apparent lack of enthusiasm on the part of the teachers to continue to stress the psychological basis for meaningful learning. This issue will be important to future research studies employing the strategies, some of which are now in progress.

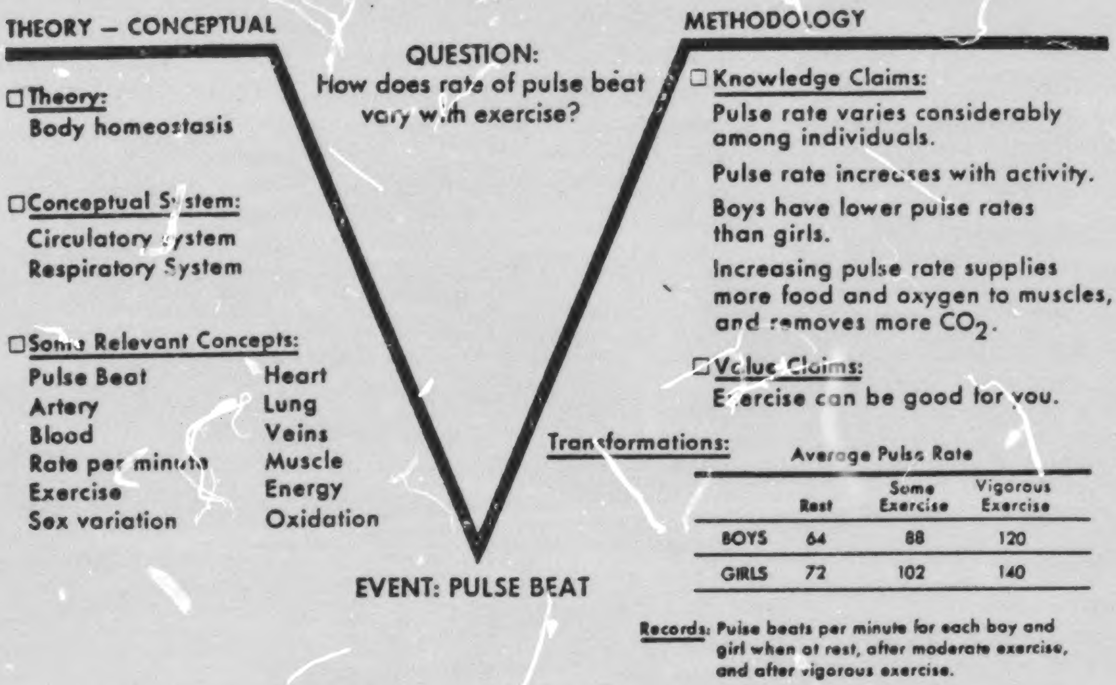
From previous work with college students, we expected acceptance of the learning strategies on the part of the students, but we were surprised to see the relative enthusiasm with which students engaged in the strategies, especially the use of concept mapping. The remainder of the report will provide greater detail on the utilization of the learning strategies as originally conceived and empirical data relative to the questions cited above.

II. A BRIEF HISTORY OF THE "LEARNING HOW TO LEARN" PROJECT

Approval of funding for the project was received in October, 1978. We had made preliminary arrangements with the Ithaca City Schools to conduct the research in the two junior high schools in that district. A meeting with administrators, principals, and science chairpersons of the two junior high schools and project staff was held in early November. Project staff had been recruited from the pool of graduate students with experience at various levels of science education. A research associate who was familiar with the theoretical foundations and activities of the planned work was employed full-time.

The administrative staff was receptive and enthusiastic, eager to see the project commence, but we were somewhat surprised to find many of the science teachers relatively cool to the prospects of a "new thing" to be dealt with. This may have been due in part to the teacher contract negotiations underway and/or other teacher-administration problems extant in Ithaca at that time. We found later that similar problems would be evident in the Vestal City Schools; once again we witnessed some of the problems associated with educational research in "real world" settings. Nevertheless, two junior high teachers from Ithaca did volunteer to begin work with use and preliminary instructional work began in November,

We began working with groups of 10 to 20 seventh grade students who volunteered to participate in "8th period," an after-school period for special activities prior to final school bus departures. For the most part, these students were highly enthusiastic and cooperative, and helpful to us. They sought examples of concepts and other items on Gowin's "V", relative to their classwork, indicating that the educational concepts we were presenting could be best understood in the context of the regular science classwork. Confident that we could begin in regular classes, we began with one class and later proceeded to work with all but one "special class" of seventh grade students. One of our first whole class sessions dealt with the effects of exercise on pulse rate, and using an overhead projector together with the blackboard, we constructed a "V" map for this activity as shown in Figure II.1. Since laboratory work was infrequent (less than once per week), we introduced some additional experiments (e.g., the study of digestion in cow's stomachs), but this proved to be too time consuming for our staff, and impractical in the long run.


THEORY — CONCEPTUAL
QUESTION:
How does rate of pulse beat vary with exercise?
METHODOLOGY
☐ Theory:
Body homeostasis
☐ Conceptual System:
Circulatory System
Respiratory System
☐ Some Relevant Concepts:
Pulse Beat
Artery
Blood
Rate per minute
Exercise
Sex variation
Heart
Lung
Veins
Muscle
Energy
Oxidation
EVENT: PULSE BEAT
☐ Knowledge Claims:
☐ Value Claims:
Transformations:
Records:

Pulse rate varies considerably among individuals.

Pulse rate increases with activity.

Boys have lower pulse rates than girls.

Increasing pulse rate supplies more food and oxygen to muscles, and removes more CO_2.

Exercise can be good for you.

Average Pulse Rate

	Rest	Some Exercise	Vigorous Exercise
BOYS	64	88	120
GIRLS	72	102	140

Records: Pulse beats per minute for each boy and girl when at rest, after moderate exercise, and after vigorous exercise.

Figure II.1. "V" completed for the laboratory exercise "Pulse Rate," an early attempt to incorporate the "V" into classroom laboratory exercises. (October, 1978)

After a few class sessions in which our project staff led instruction in the use of "V" maps, the regular classroom teacher expressed interest in utilizing the procedures as part of this teaching, so the staff's role began to shift to focussing on providing suggestions for class activities and preliminary efforts at evaluation procedures for the use with the "V". Unfortunately, the teacher decided to resign from teaching at the end of the school year and did not wish to continue his initiative in using the strategies. We sought other teachers during December and January. Contacts had been made with an eighth grade teacher in the Lansing Schools. He expressed an interest in our work and we commenced classroom instruction in January. Further information about participating schools is provided in Section III.

At the Lansing Middle School, we made rapid progress in utilizing the "V" with the much more extensive use of laboratory work associated with the INTRODUCTORY PHYSICAL SCIENCE (IPS) Program in use with eighth grade classes. Evaluation strategies were developed and evidence was obtained indicating most of the eighth grade students were highly successful in constructing "V's" and in interpreting them (in clinical interview sessions). Concept mapping was initiated in March, 1979 and this also proceeded well, and was well received by the students. We began work with concept mapping with a seventh grade science teacher in Trumansburg and made arrangements to begin work in seventh and eighth grades in Vestal, New York. At both Trumansburg and Vestal, we first introduced students to some activities illustrating meaningful learning (Appendix I, Section II) and then instructed them in concept mapping. The sequence, (1) learning activities, (2) concept mapping, and (3) "V" mapping, proved to be procedurally more appropriate and easier than the sequence beginning with "V" mapping employed in Ithaca and Lansing.

By the end of the 1978-1979 school year, we had succeeded in preparing a preliminary "Teacher's Handbook" for use with teachers wishing to use the strategies and had developed evaluation approaches for assessing students' success with concept maps, "V" maps,and science problem solving. Although all of these materials and procedures underwent extensive modification and refinement during the 1979-1980 school year, we were prepared to begin the fall semester at Trumansburg and Vestal (the Lansing teacher returned to Cornell for graduate study and became a project staff member). The turnover of participating teachers and school districts necessarily delayed progress on the project and the original twelve month schedule for the research was necessarily extended. However, the change in procedures (from staff-led instruction to teacher-led instruction) and the wide array of participating schools involved added to the promise for wider dissemination of the program, should evaluation data indicate merit to the program.

September, 1979 found Vestal in a contract dispute resulting in a "work to rule" pressure on participating teachers and slowed progress in the introduction of the strategies. At Trumansburg, however, work began immediately in the Fall semester and continued smoothly throughout the academic year. A ninth grade science teacher at South Glen Falls, New York, and a seventh grade teacher in Homer, New York expressed interest in our project. Using the preliminary Teacher's Handbook and minimum guidance from our project staff (two or three conversations), these teachers reported success and enthusiasm in implementing the strategies. Although we were slow to begin use of the learning strategies in Vestal, concept mapping instruction proceeded well in both seventh and eighth grade science class, while "V" mapping was extensively used in the eighth grade class. Procedures for instruction were further refined as the theoretical foundation of the project was more extensively articulated. This resulted in a corresponding growth in the evaluation procedures that would be employed throughout the school year. Data collection proceeded throughout the year, largely for formative evaluation purposes in the fall semester, but increasingly to serve as a basis for summative evaluation claims, especially from March-June, 1980. Detailed descriptions of instructional procedures and evaluation follow in later sections.

III. PARTICIPATING SCHOOLS AND TEACHERS

In order to characterize the schools with which we worked during the two years of our study, the following is given. In addition to information about the schools, the professional preparations and backgrounds of the four teachers involved in the project are also described. Although we began our study in the Ithaca City Schools in November, 1978, and continued some work into the Spring semester, 1979, this was essentially "pilot program" work and did not involve later performance comparisons. Figure III.1 is provided to show the relative positions of these schools to Ithaca.

Lansing is a town with a population of six thousand and is located about ten miles north of Ithaca, New York. It is a middle class community, and is classified (by self admission) as "rurban," that is, composed of rural and urban factions. There are three schools in the district: one elementary serving grades K through 4; one middle school for grades five through eight; and a high school for nine through twelve. Our project was involved with the eighth grade science teacher at the middle school which had a total student population of 375 in 1978-1979 with eighty-eight in the eighth grade. A formal science curriculum exists for the middle school and high school.

Trumansburg is located about ten miles from Ithaca on the west side of Cayuga Lake. It has a population of about three thousand, and is classified as suburban. Like Lansing, there are three schools in Trumansburg: one elementary serving grades K through four; a middle school for grades five through eight; and the high school for grades nine through

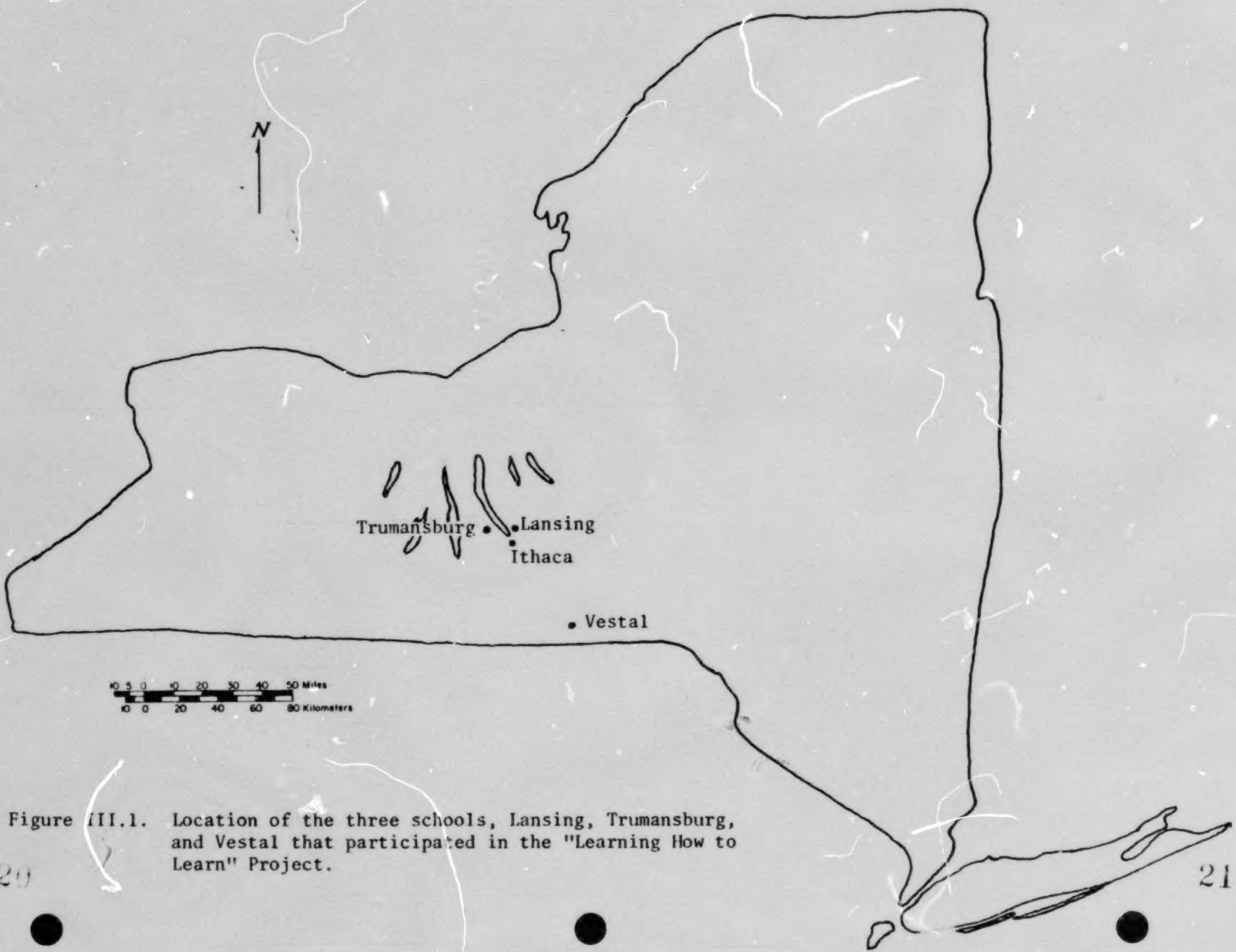

N
Trumansburg
Lansing
Ithaca
Vestal
10 5 0 10 20 30 40 50 Miles
10 0 20 40 60 80 Kilometers

Figure III.1. Location of the three schools, Lansing, Trumansburg, and Vestal that participated in the "Learning How to Learn" Project.

twelve. The student population in the middle school is slightly higher than Lansing with 393, and about one hundred of these students are seventh graders. A formal science curriculum exists for all grade levels, K through twelve.

Compared to Trumansburg and Lansing, Vestal is a very large school district, serving a community of 26,000. Vestal is located along the Southern Tier of New York state, about ten miles west of Binghamton. It is classified as suburban and is middle class. Vestal has five elementary schools, a junior high school composed of seventh and eighth grades, a ninth grade school, and one high school for grades ten through twelve. A formal science curriculum exists for grades seven through twelve, and is supervised by a district science coordinator. African Road Junior High School, the school in which we worked, enrolled almost eleven hundred students, evenly divided between the seventh and eighth grades. The Project worked with two teachers there, Mary Bente in the seventh grade, Jay Decatur in the eighth.

Doug Larison, Lansing Middle School, had been teaching for four and one-half years when he volunteered to work with our project. He earned a BS degree from Cornell University, and had been teaching physical science for four years, the last two involved with the IPS Program in Lansing. After the first year's involvement with our project, Mr. Larison returned to graduate school at Cornell to pursue his permanent certification from New York State and a Masters degree in science education. As a student during the 1979-1980 school year, Mr. Larison worked as a research assistant on the staff of the "Learning How to Learn" Project.

Sarah DeFranco, Trumansburg Middle School, was an eight year veteran when she signed on to work with our project in the Spring of 1979. She received an Associates degree from Auburn Community College, her BS from Cornell University, and her Masters degree from Elmira College. During her eight years at Trumansburg, Mrs. DeFranco was an elementary common branch teacher for one year, taught ISCS in eighth grade science for three years, and junior high biological science for seven years. Mrs. DeFranco continued with our project through its completion in June, 1980.

Jay Decatur had been teaching in Vestal for the twelve years of his career. He had attended Elmira College, SUNY at Binghamton, and LaMar Tech (Texas), and possessed thirty-eight credits beyond his BS degree. He has taught Science 7 for four years, Science 8 for nine years, and Science 9 for two years.

Mary Bente had taught for six years in the African Road Junior High School when she volunteered for our project. She majored in elementary and secondary science education at SUNY at Oneonta, and possessed thirty credits, mostly in special education, beyond her BS. Miss Bente has taught Science 8 in Vestal for three years, and has been teaching Science 7 for the past three years.

IV. MEANINGFUL LEARNING

Our first work with students was with a group of volunteer in Ithaca's Boynton Junior High School after regular classes. We offered a definition of concept* and asked the students to name other concepts and to designate the objects and/or events relevant to those concepts. The students responded to questions rapidly and were eager to get on to the discussion of "how to learn better," which we said would be the subject of the after-class sessions. They thought the distinction we made between rote learning (simple memorization of statements or definitions) and meaningful learning (relating new knowledge to knowledge previously learned) was rather obvious. They persisted: "But how do we learn to learn better?"; "How will this help me to learn science?". It became clear to us that we needed to apply one of our key principles of learning -- to relate new knowledge to things the students already knew about science, and to things they were currently learning in class.

We proceeded to introduce Gowin's "V" and the terms associated with this device, relating this to work they were doing in class; i.e., frog dissection. We also introduced some "games" as motivational devices; e.g., "see how many events you can write down in three minutes." (Most students could correctly identify six to ten events.) Although we were successful in familiarizing students with the elements of Gowin's "V", we felt that students were largely uncertain as to how the "V" related to the study of biology. This impression persisted until the Christmas break as we continued work with laboratory activities and use of the "V" (see Section VI of this report).

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*as noted earlier, we define concepts as regularities in events and objects designated by a sign or symbol.

As a result of our experiences at Ithaca's Boynton Junior High School, we decided to use some activities at Lansing Middle School specifically intended to illustrate concepts of learning. When we commenced work with students there in February, 1979, we began with activities illustrating sensory memory, short term memory, and long term memory. Modified versions of these activities are included in the Teacher's Handbook (Appendix I, Section III).

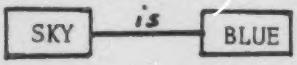
Students were highly responsive to the learning activities, and we have found this to be true with college students also. Although no formal summative evaluation of these activities was done, we found that virtually all students could distinguish between sensory, short-term, and long-term learning events. They were also successful in labeling instances of learning as essentially rote or meaningful in character. Our judgment was that these activities were successful, so we did not expend effort on evaluating this phase of the project. In retrospect, however, both teachers and students may have gained superficial knowledge of the various types of learning, and this may have limited some of the potential value in later concept mapping and "V" mapping. We would recommend further research on levels of achievement of understanding of these forms of learning, and possible relationships to success in concept mapping and "V" mapping.

In spite of the limited evaluation, both teachers and students reported satisfaction and success with the "learning activities." We also found that the introduction of concept mapping went much more smoothly when these learning activities preceded concept mapping. Since only a portion of two or three class periods is needed for these activities, teachers have all regarded them as worthy of the time involvement. An unusual number of positive responses are also being received from a published paper (Novak, 1980) in which these learning activities were presented. Unless further research should cast some doubt on the use of these activities, we recommend that they be used as introductions to the learning strategies of concept mapping and "V" mapping.

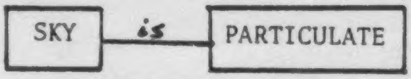
V. CONCEPT MAPPING

Introduction:

Meaningful learning requires a conscious effort on the part of the student to relate new knowledge to knowledge previously acquired. Concept mapping is a pedagogical technique to help students see explicitly how new concepts can be related to previously learned concepts. The simplest concept map would be two concepts linked by what Gardner (1980) has described as "logical connectives," e.g., words such as "because," "although," or by simple verbs. To highlight the significance of concepts, we usually place these in boxes and connect the concepts with labeled lines or rectangles. The concepts plus the verbs or logical connectives form propositions. A simple concept map for a familiar proposition would be:



Another simple concept map, but using a less familiar concept, and hence potentially less meaningful, would be:



A more complex concept map may begin to illustrate new meanings to students and hence to extend their concept meanings. Concepts grow in meaning as they become relatable to a wider array of concepts in specific propositions. An example of a more complex map can be found in Figure V.1, on page V-2.

From Ausubelian (1968, 1978) learning theory, we can expect that concept maps will have the best "psychological" organization when they are constructed hierarchically, with the most general, more inclusive concept at the top, and less inclusive concepts at the subordinate "levels." There

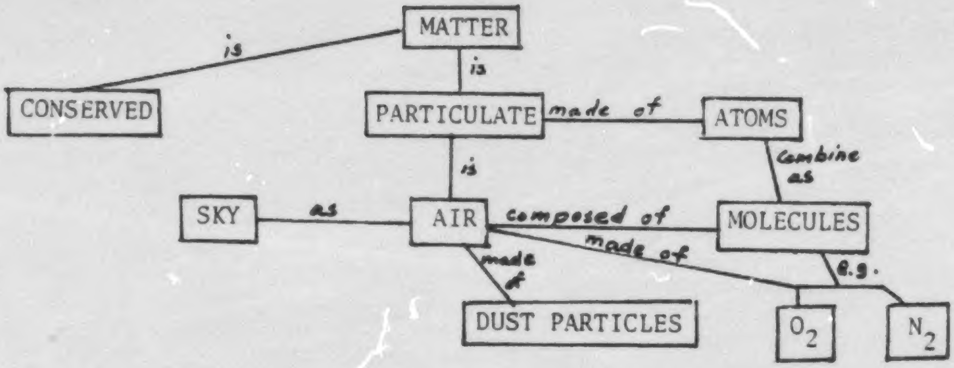


Figure V.1. A simple concept map including the concept "sky." Concept maps are composed of concepts and "linking words" which together form propositions. We have found that it is useful to construct them hierarchically, that is, proceeding from the most general, relevant concept "down" the hierarchy to more specific concepts.

is always a judgment as to what represents the best hierarchy for any body of subject matter, but people knowledgeable in the subject can generally reach a consensus on "reasonable" maps. To some extent, a concept map can be considered like a rubber sheet which can be lifted up at any one concept and make this the superordinate concepts as our focus of attention shifts from one subject area to another. For example, in Figure V.1. we could lift up the concept "air" and then the other concepts would seem to be subordinate, but still related. The crucial psychological principles are that meaning derives from perceived relationships between concepts and that learning proceeds best when "subsumption" learning is encouraged, i.e. seeing new knowledge as related to and assimilated under already known, more general relevant concepts.

In current work with children in grades one through six, we are finding that early examples of concept maps should be clearly hierarchical. Fifth and sixth graders, first presented with concept maps with a "circular" organization (subordinate concepts radiating from a central broad, inclusive concept), have difficulty in shifting later to maps with vertical hierarchy. On the other hand, first grade children presented initial examples with a vertical hierarchy could construct good concept maps given a list of familiar words selected to have potentially "top-down" hierarchical order.

From a brief introduction to concept mapping, students can quickly see that the "structure" of knowledge can be very complex, that almost any concept can be related to many other concepts, and that there is no one "best way" to represent knowledge or to draw a concept map. We have found these facts to have motivational value, since constructing a concept map proves to be something like puzzle solving, and students can compare, contrast, and criticize others' concept maps, even those made by the teacher! Furthermore, students recognize that they do know concepts that are relevant to new learning and that they can, if they try, learn new material meaningfully. Concept mapping is a natural extension of the learning activities discussed above, for it is the framework of concepts and propositions a student knows that will determine whether s/he sees meaning in a new learning task, or must resort to rote learning. Concept maps are also a way of representing externally the web of concepts and propositions in long term memory that comprises the individual's cognitive structure.

Teaching Concept Mapping :

Early in our work we found that a good way to begin concept mapping was to have students identify all of the science concepts in a segment of their textbook or laboratory study guide. This task alone often brings surprises to a teacher, for a single page may contain as many as twenty or thirty science concepts or other English words that have special meaning in the context of the science lesson. For example, words such as "greater" or "less than" may represent specific quantitative regularities, rather than a more general notion of "larger" or "smaller."

Next we asked the student to order or rank these concepts in a list so that the most "important" or most general concept is first and the less important, more specific concepts come later. While the first step (identifying concepts) requires some thought and careful reading, the second step really becomes challenging. Students need to evaluate what the reading passage is all about; what is the most important idea of the concepts being discussed, and what is relatively less important. But in spite of this challenge (or is it because of it?), students generally give positive reports on their reactions to concept mapping. (Some quotes from students will be given below.)

We have also tried having students prepare concept maps in small groups (two to four students), and to reach a consensus on their map. Much lively discussion commonly ensues. Another strategy employed has been to have individuals or groups draw their maps on the blackboard or prepare their maps on transparencies to be shown on the overhead projector. The discussions that follows usually challenges the construction of the map -- what concepts are at the top or at the bottom, and what kinds of linkages are illustrated on the concept map.

Another approach we used was to pass out small paper rectangles of two sizes and have students write concept labels on the larger pieces and the "logical connectives" on the others. Figure V.2 shows an example of such a map. The advantage to this approach is that maps can easily be rearranged, and sometimes students are asked to see if they are still satisfied with the map. A restructed map will often retain unique features, and students come to appreciate some of the idiosyncratic nature of meaningful learning. Transparent tape can be used to hold the paper slips in place, and students report that concept maps become good study materials for later review sessions in class.

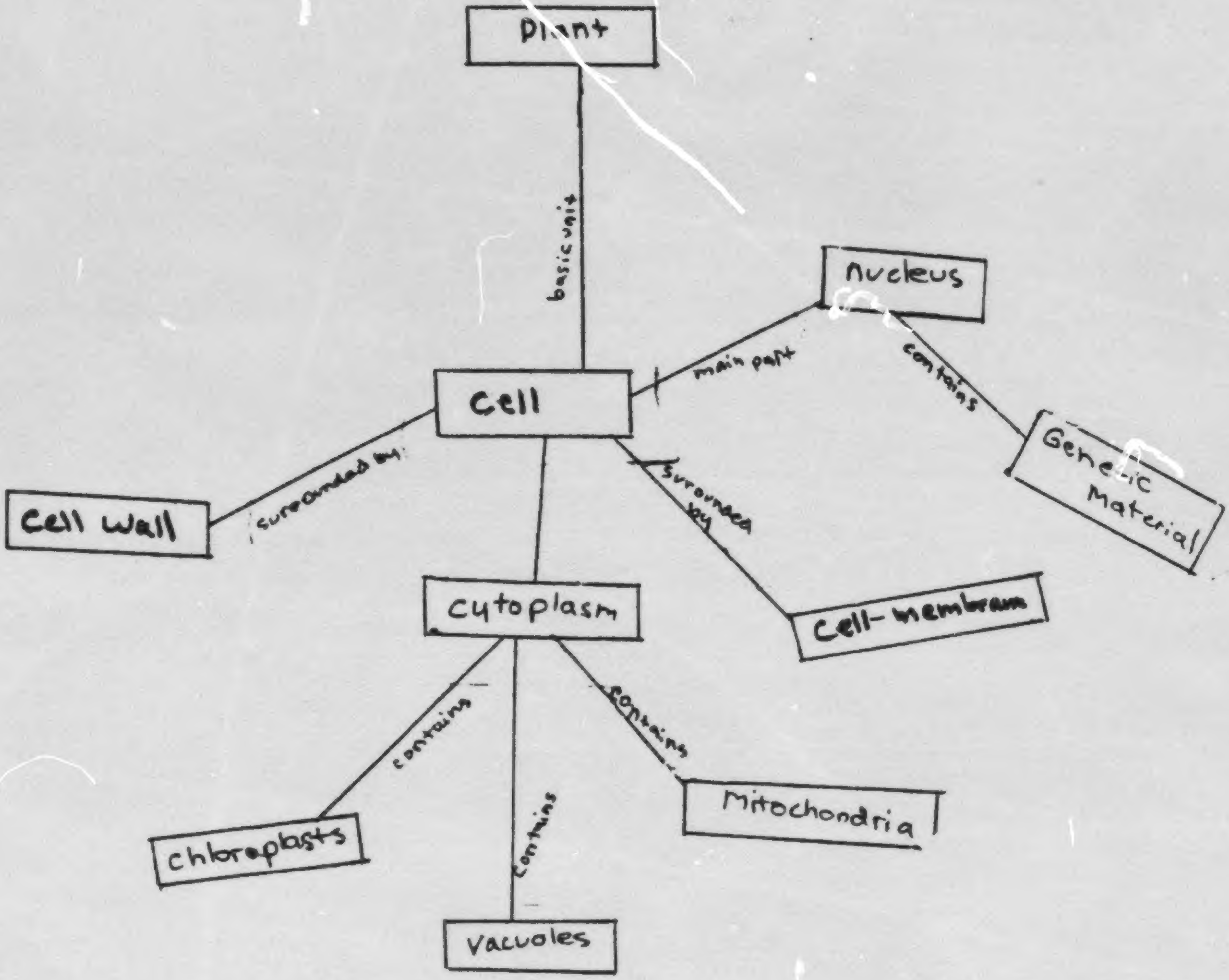

Plant
basic unit
Cell
main part
Nucleus
contains
Genetic Material
surrounded by
Cell Wall
surrounded by
Cell-membram
Cytoplasm
contains
Chloroplasts
contains
Vacuoles
contains
Mitochondria

Figure V.2. Concept map developed by Student #261 from a paragraph on plant cells. (May, 1980).

Evaluation of Concept Maps:

Previous research employing concept mapping (Stewart, VanKirk, and Rowell, 1979; Moreira, 1979) had provided some foundation for our evaluation program. However, we found it necessary to construct much more explicit criteria for evaluation, and also criteria simple enough to be used by the busy classroom teacher. In order to refine our evaluation criteria, we began by using a clinical interview approach (Pines, et al., 1978) with students constructing a map from a specially written paragraph (see pages V-11 through V-24 for the paragraphs), and then explaining to the interviewer why they constructed the map as they did. Appendix II gives complete transcripts from two clinical interviews.

The clinical interview protocol included the following elements. First, we would ask the student to read a paragraph that was based on material that the student had already had in class. The paragraph was purposefully short, not more than fifty words, with usually no more than ten relevant concepts. After the student had read the paragraph, we asked him/her to write the major concepts on small pieces of 1" x 3" green paper, and to use other slips of paper (1/4" x 2" yellow) to represent the lines between the concepts. Students were not told to write on the lines, but only that these yellow slips represented the lines. We wanted to determine if the students knew what they should write on these lines, a fundamental element of concept mapping. The reason that we adopted the use of pieces and slips of paper, rather than having the interviewee write directly on sheets of paper, was to facilitate any changes of the map during the interview.

Once the concept map was completed, we asked the interviewee several questions relative to the construction of the map: why that one concept was on top, explain the relationships represented by the yellow lines, why are certain concepts were lower on the map, and we probed generally the structure and content of the map. Of course, tape recordings were made of each of these initial interviews, and the concept maps were Scotch-taped down into a more permanent form of records. Transcripts of each of the audiotapes for these and subsequent interviews were also made.

These initial interviews were conducted with approximately eight students from Trumansburg during late May and early June, 1979. With the end of the school year quickly approaching, we decided that this small number was enough to begin developing the criteria for assessing the concept mapping strategy (see the next part of this section.)

During the early Fall, 1979, the staff again turned to the interviews to revise them. It was felt that the interviews should also probe how the students feel about concept mapping, and in addition to determining whether students could actually construct them. This, then, was included in the interview protocol. A preliminary set of interviews was conducted in Trumansburg again in October, 1979. The intention of this set was to test the adequacy of the protocol and to acquaint new staff members who had joined us that semester with the interviewing technique. From these initial interviews in October, the staff revised the paragraph that was to be presented to the students during subsequent interviews.

During the course of several series of interviews over the year, the staff decided to use a larger piece of paper (18" x 12") as the base for the students' maps. The small size of the 8-1/2" x 11" sheets of paper caused cramping of the concept map. The larger sheets were less confining, and less confusing. Our Xerox machine could reduce these larger maps to a more manageable size for record keeping with transcripts of the interviews.

Throughout the Summer, 1979, the staff, using the preliminary interviews from the previous Spring in Trumansburg, tried to devise adequate criteria for assessing the concept maps that students would construct during the clinical interviews. Finally, in the Fall, new staff members provided a much-needed injection of new ideas, and facilitated the creation of the desired criteria. One very fruitful session in late September resulted in several characteristics which would become the core of the evaluation criteria. Essentially, the staff asked what characterized a concept map, identified those elements (Stewart, et al., 1979) and then developed a scoring scale that would indicate students' performances relative to those elements.

Figure V.3 is a description of the "final" criteria developed for scoring concept maps. These criteria were used to assess all the concept maps that were collected during the school year 1979-1980, and form the basis of the reported data in the following pages.

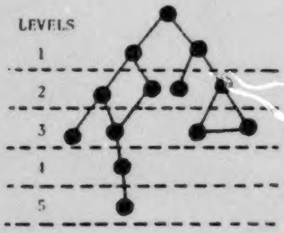
These criteria were used to construct a less rigorous form for assessing student-constructed concept maps. Essentially, this other form was developed to provide the teacher who intends to implement this strategy in the classroom with an alternative which might be more manageable than the more comprehensive form. This more general form is reported in the Teacher's Handbook, page V-3 (Appendix I).

Ignore all parts of the map for relationships criterion if no relationships are explicitly identified by proper labeling of the connecting line. See Appendix I, Section V for samples of scored concept maps.

RELATIONSHIPS: One point is given for each relationship between two concepts provided the relationship is content correct and explicitly stated. No additional credit is awarded for duplication of the same relationship on the concept map.

HIERARCHY: Points are awarded depending on the degree of hierarchy in the concept map. The number of points given for hierarchy depends upon the number of levels that are identified in the constructed map. Use the map to the right for illustration.

One point is given for at least one correct relationship per level, up until two levels beyond the last branching if the map remains linear.



BRANCHING: The branching of the concept map refers to the level of degree of differentiation among the concepts that are illustrated in the hierarchy. That is, it attempts to rate the degree that specific concepts are connected to more general or inclusive concepts. That rating is as follows:

One point for the first branching where two or more concepts are connected to the concept above.

Three points for any subsequent branching where there is an example of two or more concepts connected to a concept above. The illustrated map above would receive a score of seven; 1 point for Level 1, and three points each for Levels 2 and 3. Note that since no branching occurs in Levels 4 and 5, no further points are awarded for this criterion.

GENERAL TO SPECIFIC: The concept map receives an additional rating for illustrating a general to specific pattern. Whether one concept is more general than the ones below it depends upon the line which connects the two concepts. If no general to specific relationships exist, or less than 10% of the relationships are general to specific, the map receives a score of zero.

If 10 - 29% are correct = 1 point
30 - 49% " = 2 points
50 - 69% " = 3 "
70 - 89% " = 4 "
90 - 100% " = 5 "

CROSS LINKS: Interratedness in a student's concept map indicates an integration of concepts, and is depicted as cross links on the concept map. Cross links show a relationship between concepts on one branch of the hierarchy with concepts on another branch. Notice the two examples of cross links in the illustration above. A rating of one point is given for each cross link showing the integration among concepts. No additional points are awarded for duplication of the same cross link, that is, showing the same integration of concepts.

Figure V.3. A scoring key developed for providing numerical values to major elements of concept maps. This comprehensive form might be used to help teachers and students understand the characteristics of a good concept map.

A word of caution is in order. While the criteria for the assessment of student-constructed concept maps do consider structure as well as content, the maps are an externalization of the student's cognitive structure. While we believe that the concept maps reflect, in some degree, the cognitive structure of the individuals, we do not know what systematic errors are introduced in this representation. Thus, scores that the students receive on their maps may not be as valid as more probing and more time-consuming clinical interviews would offer. However, in the two years of the project's work, we were unable to devise an instrument that would consider all three of the elements that impinge on the construction of concept maps: ability to construct the map, the content correctness as represented on the maps, and the map as a reflection of the cognitive structure. Further research with this strategy and assessment criteria may result in a more accurate, and thus, more valid use of the instrument.

Evaluation of Concept Maps during 1979-1980:

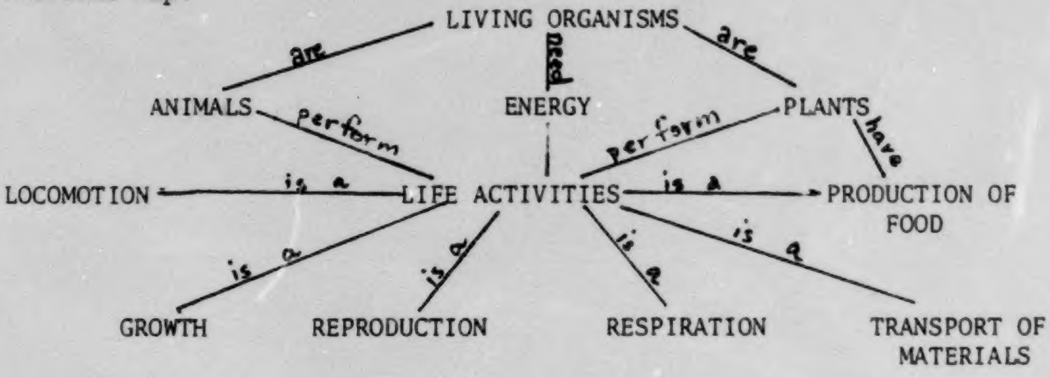
Evaluation of the concept mapping strategy began with the clinical interviews in Trumansburg in November, 1979. A paragraph was designed from the initial paragraph used in the preliminary October interviews. (The results of these October interviews will not be reported since their major intention was to familiarize the staff with the clinical interviewing strategy.) A baseline concept map was constructed from the paragraph. The function of this baseline map, and all the other paragraphs that were used in this phase of the evaluation, was to provide a meterstick to evaluate the students' performances. This baseline map was not an "ideal map" (although we did use that term for a time), but only provided a guideline for assessment.

In fact, many of the maps constructed by the students reflected higher scores on certain criteria than our own baseline maps represented.

What follows are the results from the series of clinical interviews and class activities involved with making concept maps from selected paragraphs. Each section is introduced by the paragraph used, the baseline map for that paragraph, and the scoring for that baseline map according to the criteria given in Figure V.2 on page 7 of this section. Tables and graphs showing the mean percent-of-baseline values for each paragraph are provided, as well as frequency distributions.

> *LIVING ORGANISMS ALL NEED ENERGY. PLANTS AND ANIMALS USE ENERGY FOR LIFE ACTIVITIES. SOME LIFE ACTIVITIES THAT BOTH PLANTS AND ANIMALS HAVE ARE GROWTH, REPRODUCTION, RESPIRATION, AND TRANSPORT OF MATERIALS. A LIFE ACTIVITY FOUND ONLY IN GREEN PLANTS IS THE PRODUCTION OF FOOD. ANIMALS CANNOT PRODUCE THEIR OWN FOOD, SO THEY NEED THE LIFE ACTIVITY OF LOCOMOTION TO FIND FOOD.*

Baseline Map:


LIVING ORGANISMS
are
need
are
ANIMALS
ENERGY
PLANTS
perform
perform
have
LOCOMOTION
is a
LIFE ACTIVITIES
is a
PRODUCTION OF FOOD
is a
is a
is a
is a
GROWTH
REPRODUCTION
RESPIRATION
TRANSPORT OF MATERIALS

Scoring:

Relationships (R) - 14
Hierarchy (H) - 3
Branching (B) - 10
General to Specific (G/S) - 5
Cross Links (CL) - 4
TOTAL (Tt) - 36

Figure V.4. Baseline map for ""Living Organisms" Paragraph. Trumansburg, seventh grade, November, 1979 and March, 1980.

Table V.1. Percentage scores for each criterion and total for concept maps prepared from Paragraph #1 in relation to the baseline scores established for that paragraph. (N = 72) For some criteria, the percentage score is greater than 100%. This is due to students scoring higher in those criteria than our own baseline map.

CRITERIA	MEAN (%)
Percent Relationships (R)	69.69
Percent Hierarchy (H)	120.26
Percent Branching (B)	47.64
Precent General to Specific (G/S)	82.78
Percent Cross Links (CL)	11.11
Percent Total (Tt)	63.13

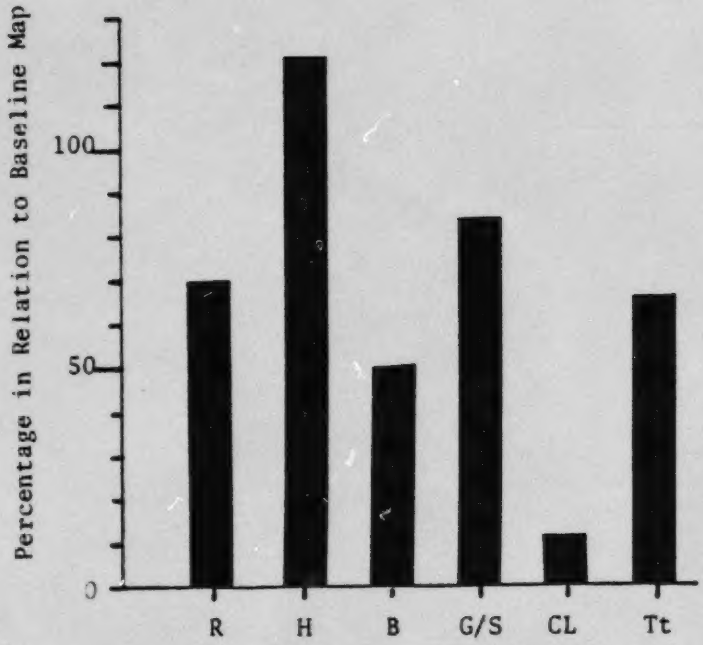


Figure V.5. Percentage Scores for each criteria (R = relationships; H = hierarchy; B = branching; G/S = general to specific; CL = cross links) and total score (Tt) for concept maps prepared from Paragraph #1. Percentage score in relation to baseline concept map for that paragraph.

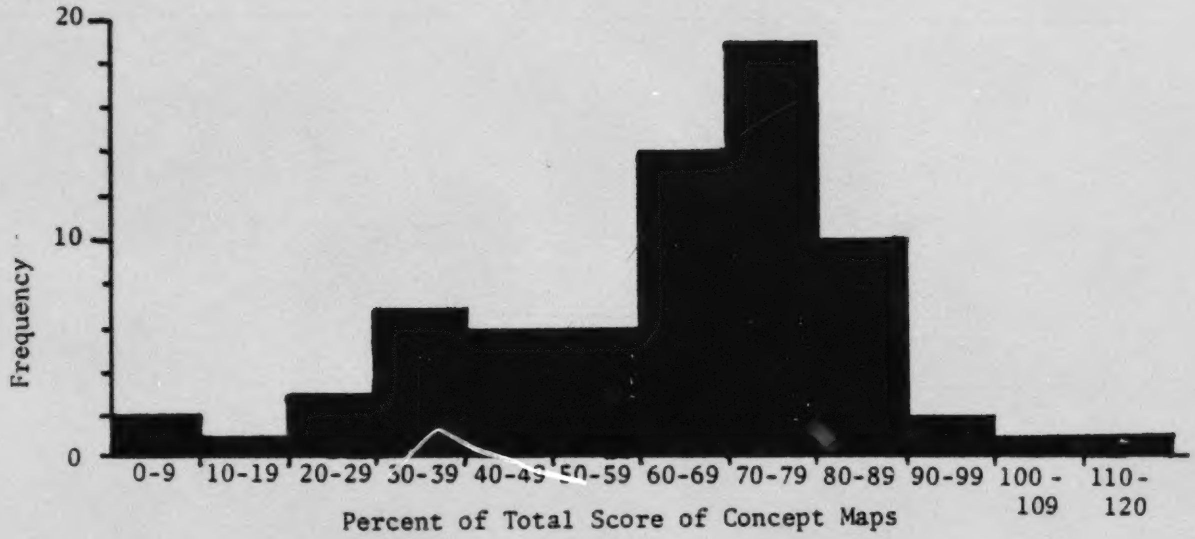
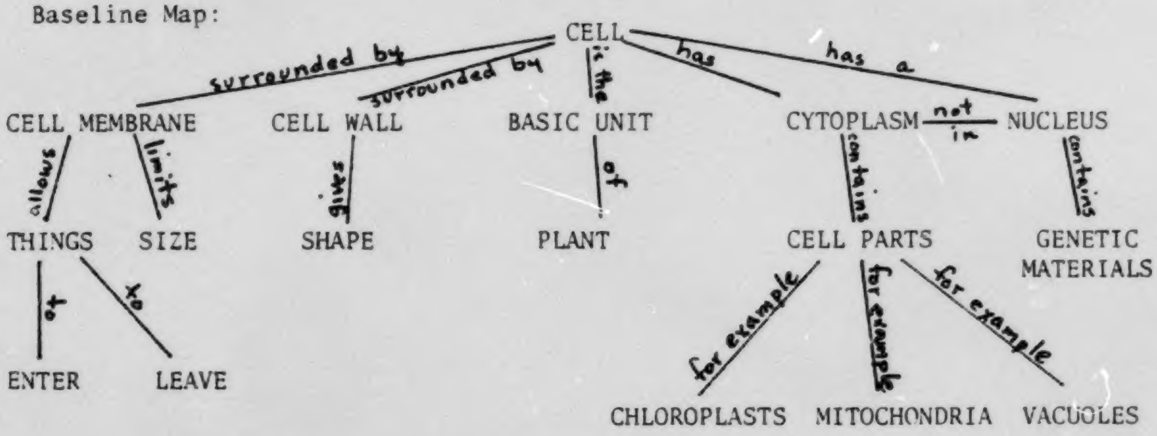


Figure V.6 Frequency distribution for total percentage.of concept maps prepared from Paragraph #1 in relation to baseline map. (N = 72)

Paragraph #2

THE CELL IS THE BASIC UNIT OF A PLANT. IT IS SURROUNDED BY A CELL MEMBRANE AND A CELL WALL. THE CELL MEMBRANE LIMITS THE SIZE OF THE CELL AND ALLOWS ONLY CERTAIN THINGS TO ENTER OR LEAVE THE CELL. THE CELL WALL GIVES SHAPE TO THE PLANT. THE CYTOPLASM OF THE CELL CONTAINS THE CELL PARTS WHICH INCLUDE MITOCHONDIRA, VACUOLES, AND CHLOROPLASTS. THE NUCLEUS, WHICH IS NOT IN THE CYTOPLASM, CONTAINS GENETIC MATERIAL.

Baseline Map:


CELL
surrounded by
surrounded by
is the
has
has a
CELL MEMBRANE
CELL WALL
BASIC UNIT
CYTOPLASM
not in
NUCLEUS
allows
limits
gives
of
contains
contains
THINGS
SIZE
SHAPE
PLANT
CELL PARTS
GENETIC MATERIALS
to
to
for example
for example
for example
ENTER
LEAVE
CHLOROPLASTS
MITOCHONDRIA
VACUOLES

Scoring:

Relationships (R)	- 17	General to Specific (G/S)	- 5
Hierarchy (H)	- 3	Cross Links (CL)	- 1
Branching (B)	- 10	Total Score (Tt)	- 36

Figure V.7. Baseline Map for "Cell" paragraph. Vestal, seventh grade, January, 1980 and May, 1980.

Table V.2. Percentage scores for each criterion and total for concept maps prepared from Paragraph #2 in relation to the baseline scores established for that paragraph. (N = 67)

CRITERIA	MEAN (%)
Percent Relationships (R)	33.91
Percent Hierarchy (H)	91.04
Percent Branching (B)	27.31
Percent General to Specific (G/S)	55.82
Percent Cross Links (CL)	1.49
Percent Total (Tt)	36.37

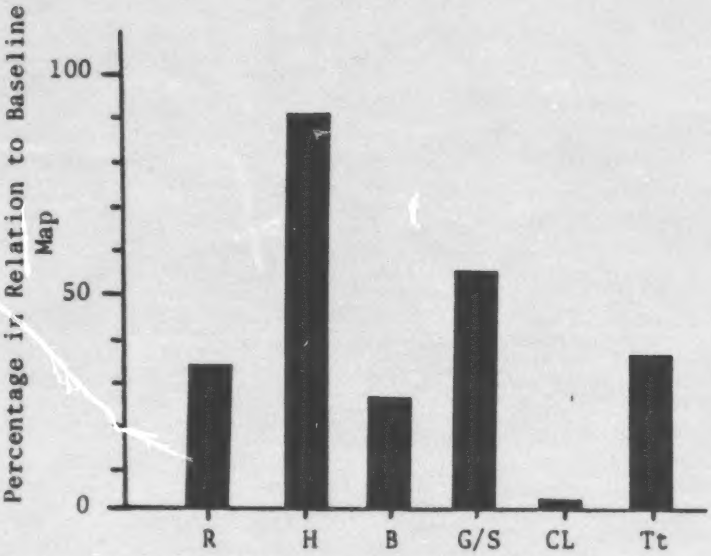


Figure V.8. Percent Scores for each criteria (see Figure V.5 for symbol codes) and total (Tt) scores for concept maps prepared from Paragraph #2. Precentage score in relation to baseline concept map for that paragraph.

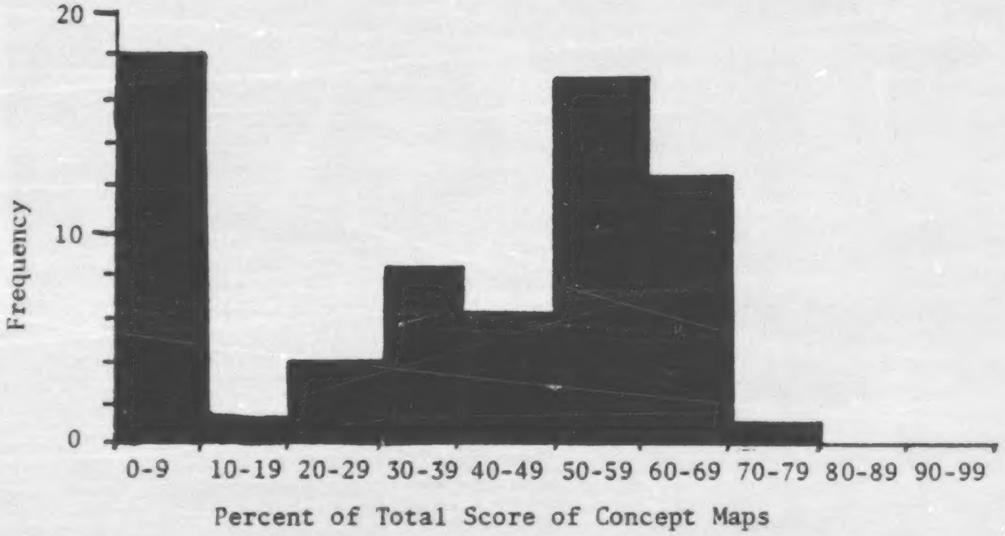
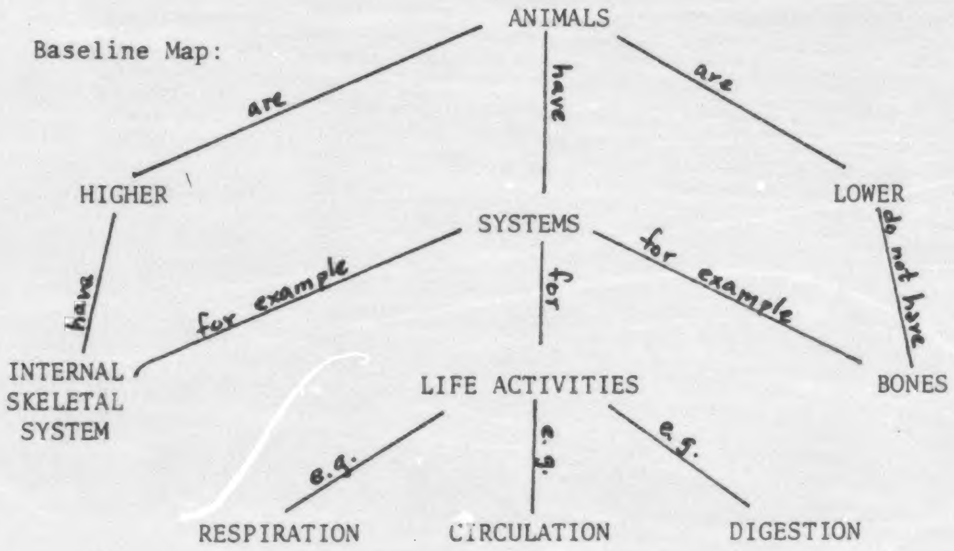


Figure V.9. Frequency distribution for total percentage of concept maps prepared from Paragraph #2 in relation to baseline map. (N = 67)

Paragraph #3

ANIMALS ALL HAVE SYSTEMS. HIGHER ANIMALS AND LOWER ANIMALS USE SYSTEMS TO PERFORM LIFE ACTIVITIES. SOME LIFE ACTIVITIES THAT BOTH HIGHER AND LOWER ORGANISMS HAVE ARE RESPIRATION, CIRCULATION, AND DIGESTION. A SYSTEM FOUND ONLY IN HIGHER ANIMALS IS AN INTERNAL SKELETAL SYSTEM. LOWER ANIMALS DO NOT HAVE BONES.

Baseline Map:


ANIMALS
are
have
are
HIGHER
SYSTEMS
LOWER
have
for example
for
for example
do not have
INTERNAL SKELETAL SYSTEM
LIFE ACTIVITIES
BONES
e.g.
e.g.
e.g.
RESPIRATION
CIRCULATION
DIGESTION

Scoring:

Relationships (R) - 11

Hierarchy (H) - 3

Branching (B) - 7

General to Specific (G/S) - 5

Cross Links (CL) - 2

Total (Tt) - 28

Figure V.10. Baseline map for "Animals" paragraph with scoring according to comprehensive form for assessing constructed concept maps. Trumansburg, seventh grade, April, 1980.

Table V.3. Percentage scores for each criterion and total for concept maps prepared from Paragraph #3 in relation to the baseline scores established for that paragraph. (N = 36) For some criteria the percentage score is greater than 100%. This is due to students who scored higher than our own baseline map for that criterion.

CRITERIA	MEAN (%)
Percent Relationships (R)	80.27
Percent Hierarchy (H)	105.58
Percent Branching (B)	71.75
Percent General to Specific (G/S)	81.11
Percent Cross Links (CL)	22.22
Percent Total (Tt)	77.53

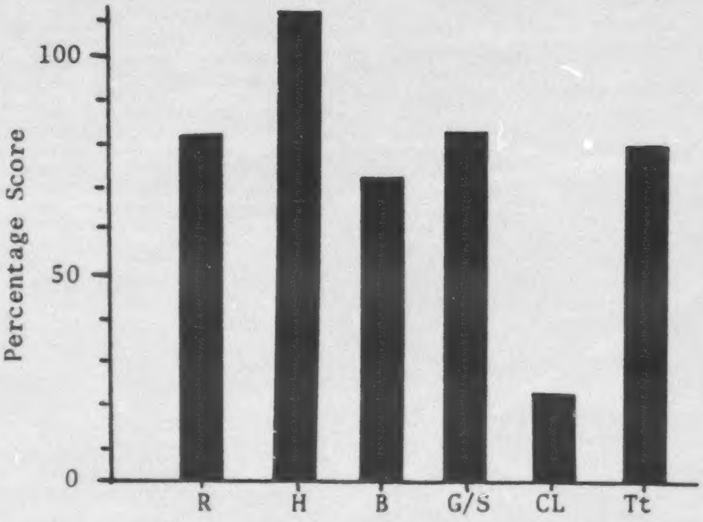


Figure V.11 Percent Scores for each criterion (see Figure V.5 for symbol codes) and total (Tt) scores for concept maps prepared from Paragraph #3. Percentage score in relation to baseline concept map for that paragraph, some criteria the percentage score is greater than 100%.

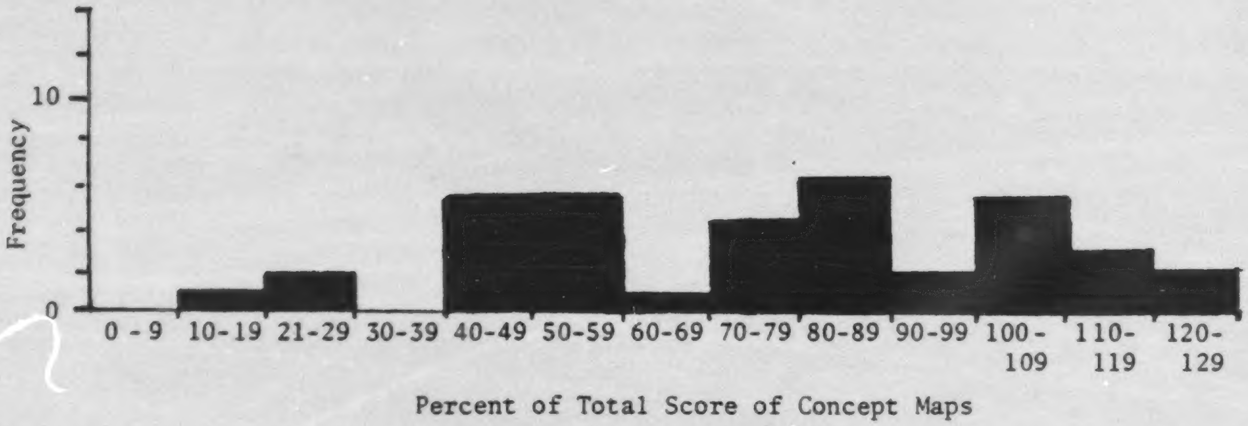
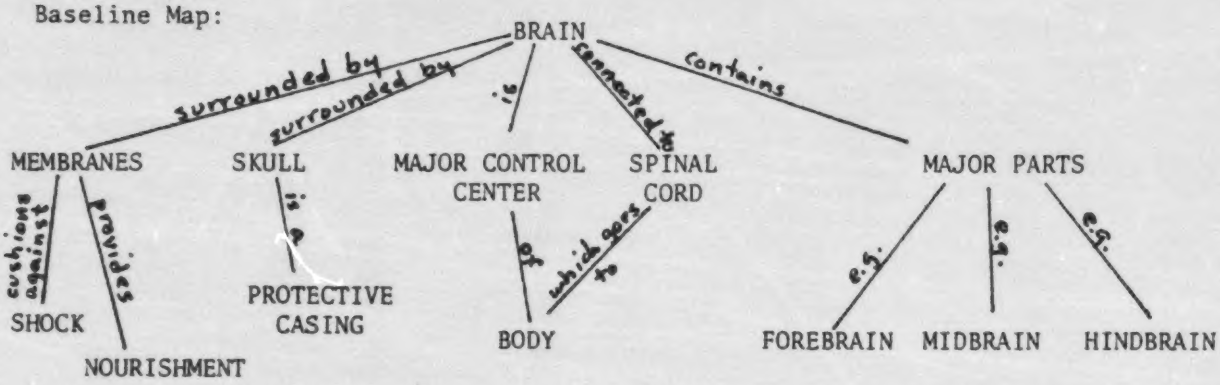


Figure V.12. Frequency distribution for total percentage of concept maps prepared from Paragraph #3 in relation to baseline map. (N = 36)

Paragraph #4

THE BRAIN IS THE MAJOR CONTROL CENTER OF THE BODY. IT IS SURROUNDED BY MEMBRANES AND THE SKULL. THE MEMBRANES CUSHION AGAINST SHOCK AND PROVIDE NOURISHMENT. THE SKULL IS A HARD PROTECTIVE CASING. THE BRAIN CONTAINS THREE MAJOR PARTS, THE FOREBRAIN, THE MIDBRAIN, AND THE HINDBRAIN. THE SPINAL CORD, WHICH IS NOT PART OF THE BRAIN, IS A MAJOR CONNECTION CENTER TO THE REST OF THE BODY.

Baseline Map:


BRAIN
surrounded by
surrounded by
is
connected to
contains
MEMBRANES
SKULL
MAJOR CONTROL CENTER
SPINAL CORD
MAJOR PARTS
cushions against
provides
is a
of
which goes to
e.g.
e.g.
e.g.
SHOCK
NOURISHMENT
PROTECTIVE CASING
BODY
FOREBRAIN
MIDBRAIN
HINDBRAIN

Scoring:

Relationships (R)	- 13	General to Specific (G/S)	- 5
Hierarchy (H)	- 2	Cross Links (CL)	- 1
Branching (B)	- 7	Total Score (Tt)	- 28

Figure V.13. Baseline map for "Brain" paragraph with scoring according to comprehensive form for assessing constructed concept maps. Vestal, seventh grade, May, 1980.

Table V.4. Percentage scores for each criterion and total for concept maps prepared from Paragraph #4 in relation to the baseline scores established for that paragraph. (N = 54)

CRITERIA	MEAN (%)
Percent Relationships (R)	50.59
Percent Hierarchy (H)	50.46
Percent Branching (B)	42.69
Percent General to Specific (G/S)	76.67
Percent Cross Links (CL)	3.70
Percent Total (Tt)	55.20

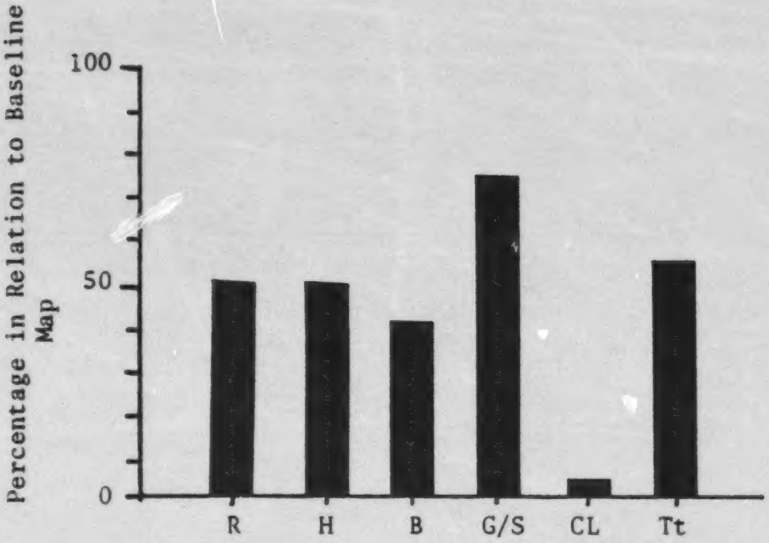


Figure V.14 Percent scores for each criterion (see Figure V.5 for symbol codes) and total scores (Tt) for concept maps prepared from Paragraph #4. Percentage score in relation to baseline concept map for that paragraph.

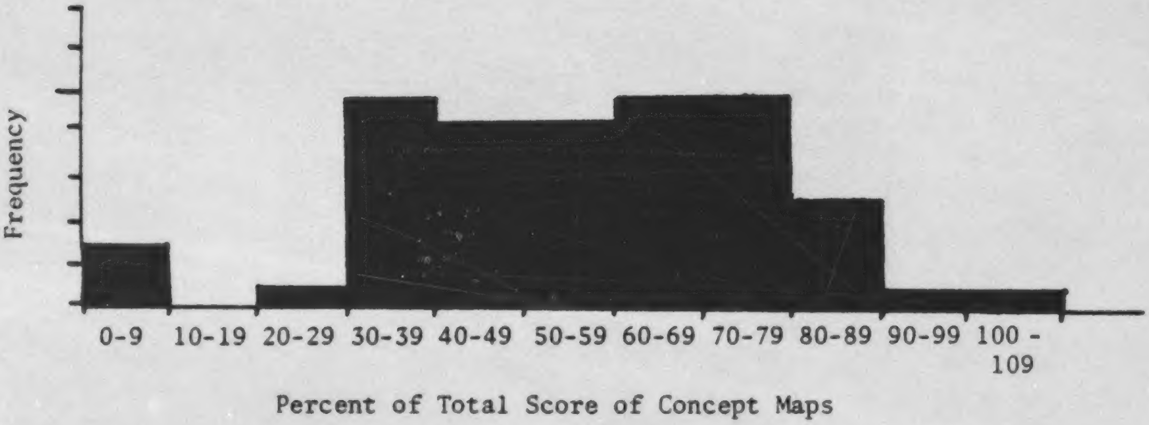
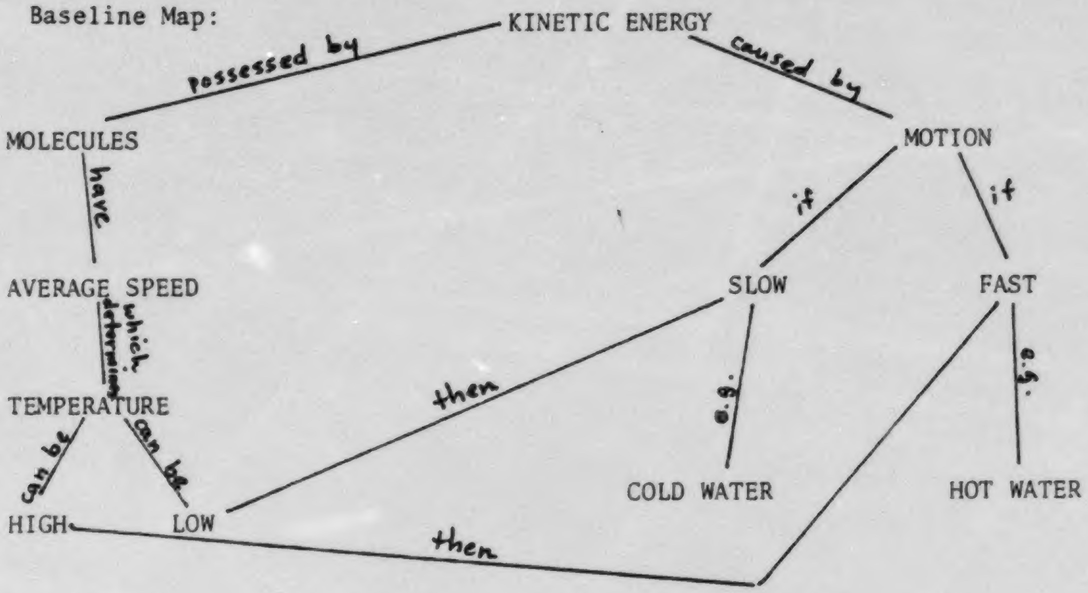


Figure V.15. Frequency distribution for total percentage of concept maps prepared from Paragraph #4 in relation to baseline map. (N = 54)

Paragraph #5

ALL MOLECULES HAVE KINETIC ENERGY CAUSED BY THEIR MOTION. THE AVERAGE SPEED OF THE MOLECULES IN A PIECE OF MATTER DETERMINES ITS TEMPERATURE. THE FASTER THE AVERAGE SPEED OF THE MOLECULES IN A PIECE OF MATTER, THE HIGHER THE TEMPERATURE. THE SLOWER THE AVERAGE SPEED OF THE MOLECULES IN A PIECE OF MATTER, THE LOWER THE TEMPERATURE. HOT WATER MOLECULES HAVE A FASTER AVERAGE SPEED THAN COLD WATER MOLECULES.

Baseline Map:


KINETIC ENERGY
possessed by
caused by
MOLECULES
MOTION
have
if
if
AVERAGE SPEED
which determines
SLOW
FAST
TEMPERATURE
then
e.g.
e.g.
can be
can be
COLD WATER
HOT WATER
HIGH
LOW
then

Scoring:

Relationships (R) - 12
Hierarchy (H) - 3
Branching (B) - 14
General to Specific (G/S) - 5
Cross Links (CL) - 2
Total Score (Tt) - 36

Figure V.16. Baseline map for "Kinetic Energy" paragraph with scoring according to comprehensive for assessing constructed concept maps. Vestal, eighth grade, January, 1980 and May, 1980.

Table V.5. Percentage scores for each criterion and total for concept maps prepared from Paragraph #5 in relation to the baseline scores established for that paragraph. (N = 58)

CRITERIA	MEAN (%)
Percent Relationships (R)	32.71
Percent Hierarchy (H)	68.48
Percent Branching (B)	10.24
Percent General to Specific (G/S)	66.21
Percent Cross Links (CL)	4.31
Percent Total (Tt)	30.05

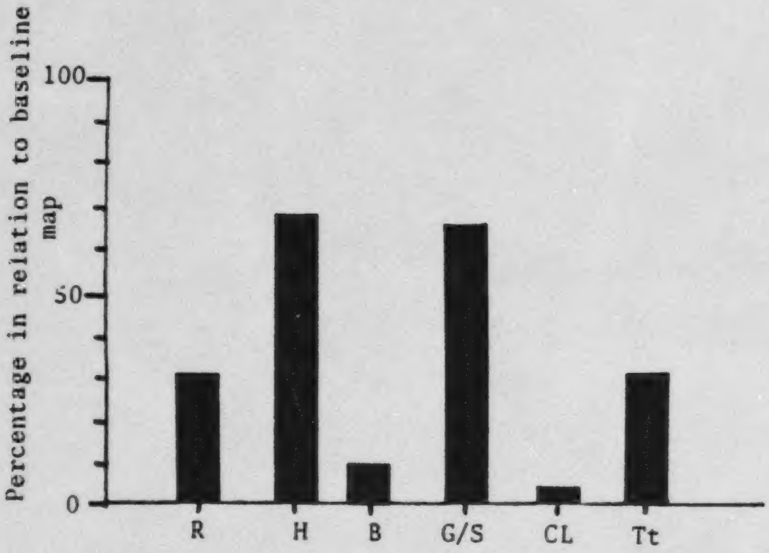


Figure V.17 Percent scores for each criterion (see Figure V.5 for symbol codes) and total scores (Tt) for concept maps prepared from Paragraph #5. Percentage score in relation to baseline concept map for that paragraph.

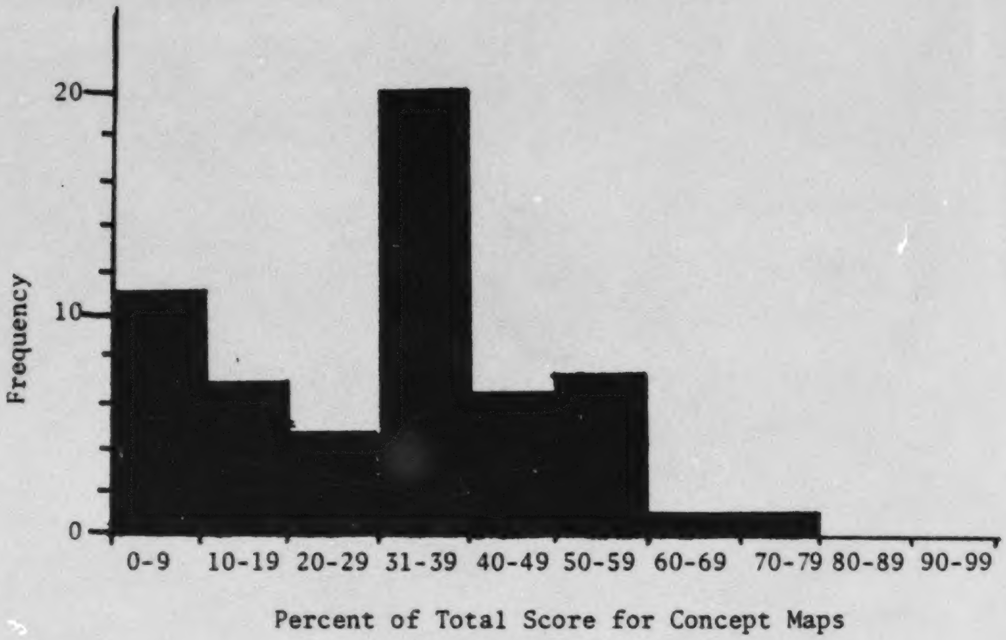
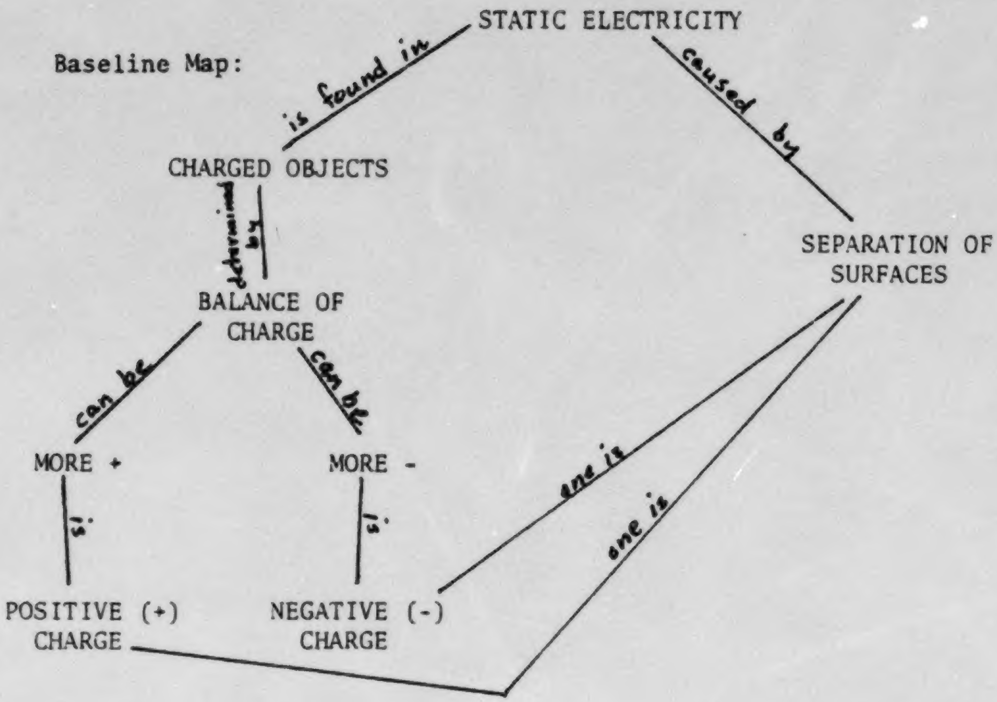


Figure V.18 Frequency distribution for total percentage of concept maps prepared from Paragraph #5 in relation to baseline map. (N = 58)

Paragraph #6:

CHARGED OBJECTS HAVE STATIC ELECTRICITY CAUSED AS SURFACES ARE MOVED APART. CHARGE IS DETERMINED BY THE BALANCE OF POSITIVE AND NEGATIVE CHARGES. IF THERE ARE MORE NEGATIVE THAN POSITIVE CHANGES, THE OBJECT IS NEGATIVELY CHARGED. IF THERE ARE MORE POSITIVE THAN NEGATIVE CHARGES, THE OBJECT IS POSITIVELY CHARGED. SOMETIMES WHEN TWO SURFACES ARE MOVED APART, ONE SURFACE IS POSITIVE AND THE OTHER IS NEGATIVE. FOR EXAMPLE, A COMB SURFACE HAS A POSITIVE CHARGE WHEN IT IS MOVED AWAY FROM THE MORE NEGATIVELY CHARGED HAIR SURFACE.

Baseline Map:


STATIC ELECTRICITY
is found in
caused by
CHARGED OBJECTS
determined by
SEPARATION OF SURFACES
BALANCE OF CHARGE
can be
can be
MORE +
MORE -
is
is
one is
one is
POSITIVE (+) CHARGE
NEGATIVE (-) CHARGE

Scoring:

Relationships (R)	- 9	General to Specific (G/S)	- 5
Hierarchy (H)	- 4	Crosss Links (CL)	- 2
Branching (B)	- 7	Total Score (Tt)	- 27

Figure V.19. Baseline map for "Static Electricity" paragraph. Vestal, eighth grade, May, 1980.

Table V.6. Percentage scores for each criterion and total for concept maps prepared from Paragraph #6 in relation to the baseline scores established for that paragraph. (N = 44)

CRITERIA	MEAN (%)
Percent Relationships (R)	64.25
Percent Hierarchy (H)	95.50
Percent Branching (B)	34.89
Percent General to Specific (G/S)	80.00
Percent Cross Links (CL)	3.41
Percent Total Score (Tt)	56.14

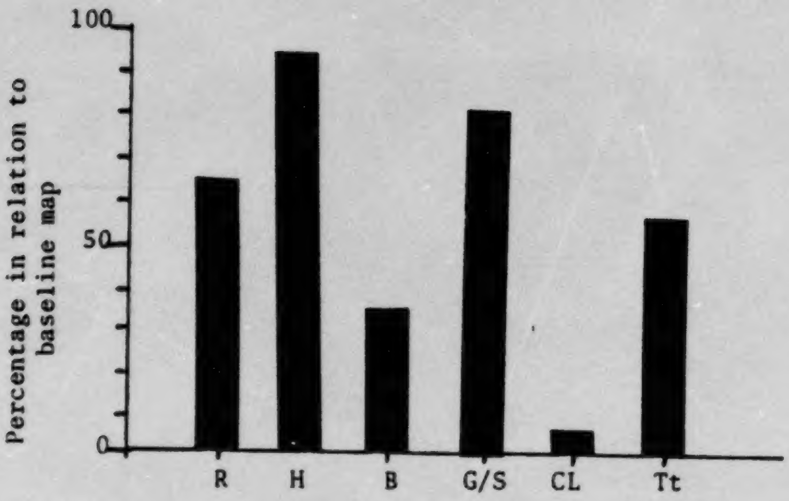


Figure V.20 Percent scores for each criterion (see Figure V.5 for symbol codes) and total scores (Tt) for concept maps prepared from Paragraph #6. Percentage score in relation to baseline concept map for that paragraph.

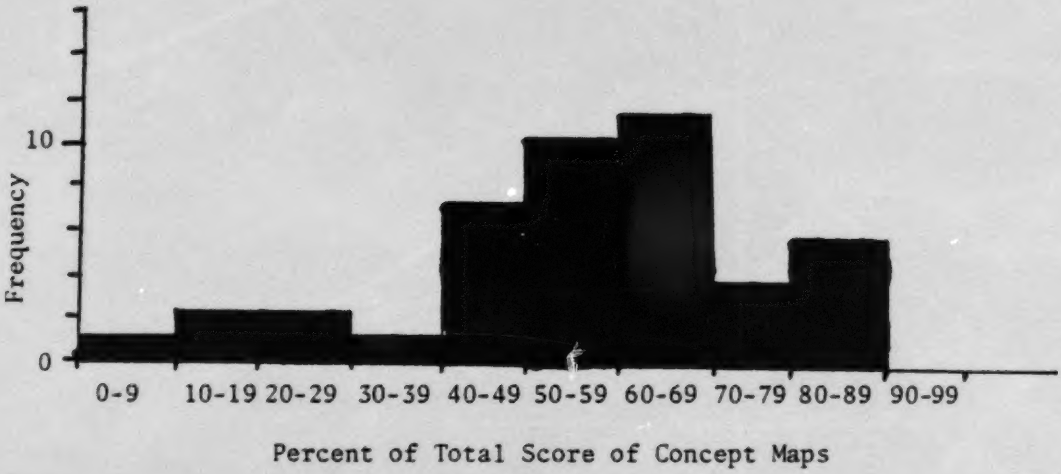


Figure V.21. Frequency distribution for total percentage of concept maps prepared from Paragraph #6 in relation to baseline map. (N = 44)

Abbreviated Analysis of Data in this Section:

Although a comprehensive statistical analysis of the data is reserved for Section IX, some preliminary remarks are in order at this state of the report.

At first glance, it can be noted that students' performances on some paragraphs were better than on others. This is due, in large part, to the groups of students that we were testing. For instance, Paragraph #1 was administered to the Trumansburg group who had received extensive training in the use of concept maps. Generally, their scores are higher than the Vestal students (Paragraph #2 for seventh grade, Paragraph #5 for the eighth grade). As was mentioned earlier, the Vestal teachers began to use our strategies comparatively late in the year (November-December, 1979) while the Trumansburg teacher began at the start of the academic year.

Comparison of Figures V.6 and V.9 illustrates another point about the role of instruction in the use of the concept mapping strategy. Very few students from the Trumansburg group (as represented by Figure V.6) received a score of zero through nine for their total score. Generally, students received that score if they did not explicitly identify the relationship between two concepts connected by lines. This exercise was considered very important in Trumansburg, but less so in Vestal. Thus, the high incidence of zero to nine scores (Figure V.9) illustrates the difference in instruction and emphasis.

Generally, the criterion of hierarchy faired better than any of the other criteria for assessing concept maps. Since hierarchy is a fundamental element of concept map, and was stressed by all the teachers in the study, the students faired better on that criterion than all the others.

Cross links, the establishement of interrelationships among concepts on a concept map, was not stressed during instruction of the concept mapping strategy. Thus, the scores for this criterion are generally low. Further, the baseline concept maps rarely contained more than one or two of these cross links. The opportunity to illustrate one by the student was limited to a kind of "all or nothing" situation.

Formative Evaluation of the Concept Mapping Strategy:

As part of the clinical interview conducted with students during 1979-1980, interviewees were asked to discuss the structure of their concept maps. Through probing, the interviewers were able to solicit some information regarding the students' understanding of the concept mapping strategy. During these interviews their attitudes about the strategy were also solicited. However, these remarks are reported in the section on attitudes (Section VIII).

Another source for the following comments came from several more informal interviews conducted with groups of students. These interviews were conducted during the last part of the project (March-April, 1980) after the students had had almost a full year of exposure to the strategies.

Several areas were probed and they will be described prior to each set of excerpts. The interviewer's questions are in caps; interviewee's responses are in lower case. If more than one student is answering the same question, the different responses are separated by a space between the responses.

WHAT IS A CONCEPT MAP?

It gives information from what we read, like it has, it's [an] organized way of writing it out ...*

Well, it's a map where you have most of the important facts of a paragraph or whatever you just read, and you make a map out of them to help you understand what it is.

Like a chart of what you've read.

WHAT IS A CONCEPT MAP, IN YOUR OWN WORDS?

Well, it's a way of helping you understand what you've been reading, or studying. It's [an] easier way instead of reading.

YOU DON'T HAVE TO READ IF YOU USE CONCEPT MAPS?

Oh, you have to read, but it makes the reading more interesting, 'cause you've got to know what you're reading to understand our labs. So it's easier to understand the labs if you do a concept map after one.

WHAT IS A CONCEPT MAP?

Hard Work!

Brackets are used in these and following excerpts to either to produce a smoother reading or to clarify the context in which the quote was made.

Each of these excerpts seem to indicate that the interviewees had some difficulty interpreting the question asked. All seem to have some idea of what a concept map is, but find it difficult to articulate its purpose. In regard to the responses relating concept maps and laboratory exercises, the teacher of that student often had the students construct concept maps prior to or immediately after doing a laboratory experiment. The concept map then became the left-hand side of the "V".

In the next question, relating to structure, the problem of vagueness in the answers seems to disappear. They are more on target when it comes to describing the structure of a concept map. The first student draws upon the analogy to describe a concept map.

HOW WOULD YOU DESCRIBE A CONCEPT MAP?

It's sort of just a pyramid and with things branching off from one another.

A PYRAMID HAS A KIND OF POINT AT THE TOP ... IS THERE A POINT AT THE TOP OF A CONCEPT MAP?

Not really, but the major, the most general thing is on the top and the more specific things breaking down.

As this student indicates, the children in our study all seem to know the rule for hierarchy and general to specific. The pyramid user above and the next interviewee reflect this.

HOW DO YOU MAKE A [CONCEPT] MAP?

Start subdividing the main subject in[to] smaller groups until you get to the smallest group.

WHAT DO YOU MEAN "SMALLER GROUPS"?

More specific ... like one subject you'd get somethings that's different in color or shape or size. [Students were involved with classification of shapes in class which is the probable reason for this response.]

Related to the structure of the concept map, we wanted to determine if the students understood the function of the lines between the represented concepts. Here are some responses from interviews that have asked for the function of the lines and what they represent.

ARE THERE THINGS THAT HOLD THE PYRAMID OF THE CONCEPT MAP TOGETHER?

I don't know ... just lines.

WHAT DO THE LINES DO?

Well, they join -- they connect ... connect the two ideas together.

WHY DO YOU HAVE A LINE BETWEEN "KINETIC ENERGY" AND "AVERAGE SPEED OF MOLECULES"?

That's what ... that's what it is. That's what it means.

DO YOU EVER WRITE ON THE LINES?

Yeah. [Student then writes "is" on the line between two concepts.]

WHAT DO THESE DO -- THE LINES?

They connect it with the important [concepts]... like "kinetic energy" has to do with "molecules," so that connects with that.

WHAT'S THE PURPOSE OF THE LINES?

'Cause if you just put "plants" and "animals" and stuck them right underneath "living organisms" and "energy" you would never know what the whole thing was about.

WHAT GOES INTO MAKING A CONCEPT MAP?

You make up at the top ... you put the main idea of the chapter and, like, say it was "molecules" or something, and then you'd write down, like, what goes into making molecules and branch off. Like a tree ... roots.

WHEN YOU SAY "BRANCH OFF," WHAT ARE THOSE BRANCHES?

They show relationships ... between them.

BETWEEN WHAT?

Between two ... concepts.

These next several excerpts are from our attempt to probe whether the students could use, or had used, the strategy of concept mapping in some other class other than science. Remembering that this project was specfically targeted to junior high science, it was interesting to record some of the students' perception of using concept mapping in other classes.

HAVE YOU EVER TRIED USING CONCEPT MAPPING IN SOME OTHER CLASS, OTHER THAN SCIENCE?

Not really. I haven't really thought about it.

DO YOU THINK IT WOULD WORK IN SOME OTHER CLASS?

Yeah. It would work in a lot of classes.

LIKE?

Like, okay, work in like math. You have a lot of steps to learn and it would help to remember basic steps and all that stuff. Work in English 'cause you got stuff like your nouns, pronouns, and stuff. Let's see, what else? Social studies 'cause you got all those dates to remember.

Although this next student has quite a different philosophy of mathematics than most students, the recurring theme that concept maps show relationships among ideas is very evident.

DO YOU THINK IT [CONCEPT MAPPING] COULD BE USED IN ANY OTHER WAYS BESIDES WHAT YOU ARE DOING NOW?

In some classes, yeah. Like social studies, or, I don't think it could be used in math.

WHAT MAKES MATH SO DIFFERENT?

Well, I guess relationships ... You know, [it] doesn't take much to figure out two plus two.

WHAT WOULD MAKE SOCIAL STUDIES MORE PRONE TO USING MAPPING?

Well, say we were studying something like the stock market. Which we are. Yeah. You could make a map of that, like, "stock market" and what goes into it, like, "stocks." Use it to explain corportation. All the different things that go into making that.... You'd see the relationship between them alot better.

In addition to determining what students thought of concept mapping, and how they would use the strategy, we also sought reactions of the teachers involved with the project. These teachers were interviewed in informal sessions, either in their homes or in school after classes were finished for the day. This was done to insure a more relaxed atmosphere with no other pressures or distractions imposing on the interview.

Although several areas, implementation, use, and philosophy behind the concept mapping and "V" strategies were discussed, only the former is reported here. Impressions on the "V" strategy are reported in the next section. Other comments, regarding other facets of the project, are reported in appropriate sections of this report.

In this series of questions, teachers were asked to discuss if concept mapping had any advantages and disadvantages, how difficult it was to implement the strategy into their classroom curriculum, and whether they saw any improvement in students' ability to use the strategy.

WHAT DO YOU FEEL ARE THE ADVANTAGES OF USING CONCEPT MAPPING?

With the concept mapping, it kind of held the kids responsible for certain vocabulary. They all of a sudden knew that they were looking up words, not only as a definition, but to show [the] relationships between words that they already knew.

... they can explain how a couple of words are related and then, not only do I know that they know the meaning of that word, but they also know the meaning of two other words, or at least one other word.

To have them do a paragraph and to make a concept map, to me, is a lot easier and a lot more enjoyable than reading a page full of definitions, because you're already trying to figure out why they're doing it. For the kids, there's a certain percentage of them that still find them very hard, and it might be because their vocabulary is just very weak.... He might be frustrated, but I don't think that's a disadvantage.

I just started tutoring [a girl]. I'm using the concept map for her as a study skill because she finds vocabulary pretty easy, but she doesn't go beyond that. She can't relate anything to anything. So we took a paragraph in a science book, we took a couple of pages actually in a science book, and I told here, "Well, what's the main vocabulary that you see time and time and time again in your reading?" We made a concept map from that, and eventually we got her to understand motion and speed and distance and time, and how to graph ....

... alot of students at the lower level can either not read [a paragraph], and get absolutely no relationships [from] the words in a paragraph.... [Concept mapping] tends to make them look for relationships, even if they don't really understand the idea of concept mapping.

It would be an advantage for me.... The first few we did, I looked over and got some ideas of what the relationships that the kids do see are.

Well, first of all, to get the kids to think about what they're read.... That lets them pick up what they feel are the main ideas, or the main concepts. It lets them tie the concepts together ...

They like to do concept mapping....

Tieing things together, seeing how they relate to each other, most importantly. But if they have fun doing it, that's good too.

WHAT ARE THE DISADVANTAGES OF CONCEPT MAPPING?

[I]f it becomes busywork where they have to read five pages and make a concept map, when they could [just] read the five pages and pick up most of it. I think if you use it correctly, it a good tool. I don't think you have to concept map everything. I think you have to be somewhat selective.

I think it should be used at the teacher's discretion, and when needed; not overdone where the kids think of it as busywork and just something the teacher is making them write out and hand in.

HOW DIFFICULT WAS IT FOR YOU TO IMPLEMENT CONCEPT MAPPING INTO YOUR CURRICULUM?

At first, I had a real hard time finding a paragraph or two that would be appropriate for it. So I went through alot of paragraphs and I realized that I couldn't even make a concept map out of them.... There's alot of deficiencies in the text.

And I think that's also something that any teacher's going to have to be willing to take the time to find out for themselves. Before you give the concept map assignment, read over the paragraph and make sure that you can come up with something, strictly from the paragraph, that even the weakest kid could pull some information together.

I think I would have to become alot more comfortable in myself [about concept mapping]. I don't know why, not afraid, but a little bit hesitant to really get into them, because I'm not that good and comfortable with [the strategy].

... I think that concept mapping is a hard thing to teach kids. I really do. At this age especially. When they are sort of set in how they read something and how they go about learning it, or outlining it,... I think it is difficult to teach them.

Sometimes, when I'll look at a concept map [that a student has done], and I'll want to change it. I'll want to draw it the way I feel it should be done. [But] if I go to the child and say, "Can you explain why you did this and this and this?" If they can, okay; if they can't, then I'll ask them "Why they did it that way, and wouldn't it be better if, and does that make more sense?"

HAVE YOU SEEN STUDENTS GETTING BETTER AT MAKING AND USING CONCEPT MAPS?

Yes, I've seen an improvement. A lot of kids don't have the real ideas. Alot of them are just putting the title as they read, as they come across topics, they will put them down. But even that helps if they are drawing lines.

Their reading assignments are better. Especially when I have them do a concept map of what they're read. If I give them definitions to do from a reading assignment, and then I give them a concept map to do on that reading assignment, they always can remember what they read and tie it to the other [parts] better when they've done a concept map.

Caveats for Using and Implementing Concept Mapping:

The following are provided in this report so that any attempt to replicate this project may not fall prey to the same mistakes that we had encountered while trying to implement these strategies.

1. Using the criteria for assessing concept maps (V-9), the teacher should identify for the students the major elements which characterize a concept map. While the teacher may opt to use the less rigorous form of evaluation (see Appendix I, page V-3) of the concept maps, these characteristics still should be taught to the students.
2. Have students identify the major concept and somehow distinguish that concept from all the other concepts represented on the map. The students could write that concept in capital letters, put a double circle around it, or write in different colors. The reason for this recommendation is to specify for the students and teacher which concept, in the students' minds, is the most general, most inclusive of the concepts represented.
3. Not all reading materials are candidates for concept maps. Often, we have found text descriptions inadequate in their relationships among concepts and/or their ability to show a hierarchical arrangement. There-

fore, the teacher should prepare concept maps of any material prior to assigning the task to the students. This way, the teacher can use the concept map as a means of judging the general worth of the reading in the text and its capacity to be concept mapped.

4. Teachers should stress the integrative aspects of concept mapping. That is, the concept map represents the relationships of meanings among concepts. We did not find teachers placing sufficient stress on this idea. We feel that if this was done more regularly, the power of the concept mapping strategy would increase for the teacher, and thus for the student.

Consistency in Concept Map Scoring:

We have noted earlier that scoring procedures for concept maps have undergone continuous revision. As we continue to use concept maps in teaching and research, new forms of scoring keys will undoubtedly result, and we would encourage continued exploration of alternative scoring procedures. For the purposes of summative evaluation, however, it was necessary to settle on a map scoring procedure and to apply it with the various classes involved in our study. The key shown in Figure V.3 of this report was used for all the concept map scores given in this report. To test the consistency with which different persons rate the same concept maps, five raters scored eighteen different concept maps applying the criteria established.

Table V.7 shows the mean map scores computed for each of the five raters and describes the raters' relevant experience with the project.

Mean scores ranged from 17.50 to 18.67. An analysis of variance was computed as shown in Table V.8. Although there was significant variation in scores on concept maps (as should be expected since these were done by different students and for different subject areas), there was no significant variation in raters' scores for the same maps ($F = 1.20$; $P > 0.32$). These data indicate that concept map ratings are relatively constant from rater to rater, assuming the raters are familiar with the strategy of concept mapping.

Table V.7. Raters, their relevant experiences, and the mean of the total scores for the eighteen concept maps they evaluated.

Rater and Experience	Mean of Total Scores (18 concept maps)
#1 - involved in project for two years	18.06
#2 - graduate student not involved with project; familiar with concept mapping and the "V"	18.67
#3 - involved in project for eighteen months	18.83
#4 - not involved with project; graduate student consultant from another university other than Cornell	17.50
#5 - involved with project for one year; teacher working part time on the project as staff member	18.50

Table V.8 Two way analysis of variance (ANOVA) on rater and concept map.

Source	df	Sum of the Squares	Mean Square	F	P
Model	21	629.7333	29.9873	6.90	.001
Error	68	295.5555	4.3464		
Corrected Total	89	925.2888			
Rater	4	20.8444		1.20	.32
Concept Maps	17	608.8888		8.24	.001

VI. THE EPISTEMOLOGICAL (KNOWLEDGE) "V"

The Evolution of the Epistemological (Knowledge) "V" for the Project:

It has already been mentioned that the epistemological "V" has been invented to show the active interplay between the conceptual structure of a discipline and the methodology employed by that discipline in some inquiry. At the point of the "V" are the events and objects which become the foci of the inquiry. As we progress up from the events and objects on the left-hand side, our conceptualizations become broader and more encompassing. As we progress up the right-hand side to the claims of our inquiry, our methodology becomes further removed from the actual events of the inquiry and involve greater manipulation of the records of those events.

The original Gowin's epistemological "V' is represented below in Figure VI.1 Upon inspection, it can be noticed that this "V" is more comprehensive than the one presented to our students in the "Learning How to Learn" Project. There were several reasons for this, and each will be discussed individually.

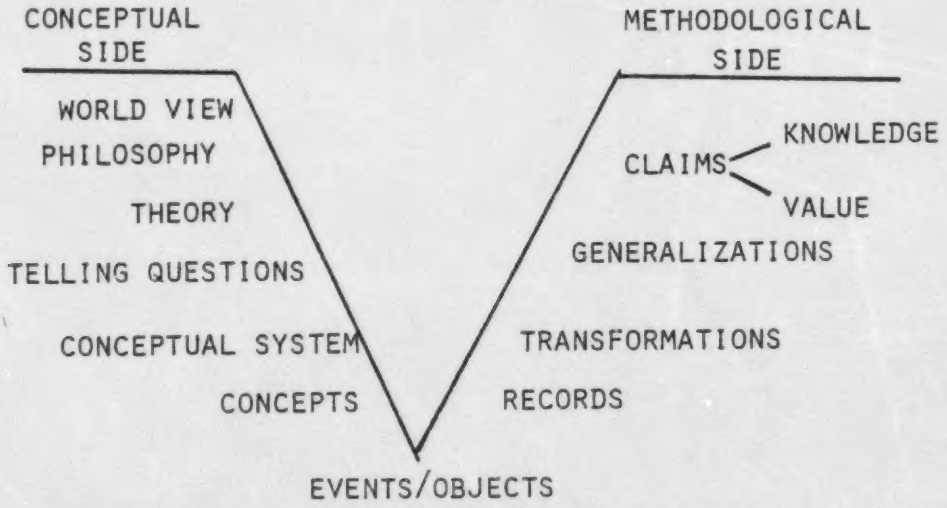

CONCEPTUAL SIDE
METHODOLOGICAL SIDE
WORLD VIEW
PHILOSOPHY
THEORY
TELLING QUESTIONS
CONCEPTUAL SYSTEM
CONCEPTS
CLAIMS
KNOWLEDGE
VALUE
GENERALIZATIONS
TRANSFORMATIONS
RECORDS
EVENTS/OBJECTS

Figure VI.1. The Original Gowin's Epistemological "V" showing the role of conceptualizations and methodology in an inquiry.

First, the left-hand side contained more terms -- world view, philosophy, theory, telling questions, conceptual systems, concepts -- than we were prepared to introduce to junior high students. It was felt that the use of only four of these terms with the exclusion of "world view" and "philosophy" would be appropriate for the junior high level. Since these students were rarely, if ever, exposed to an examination of several philosophical perspectives of science or to metaphysical principles that form the bases of world views, these aspects of the "V" were eliminated.

"Telling question" also posed a problem. Gowin (in press) defines a telling question in science as "posing a causal connection" within some phenomena of interest. To ask, and to answer, a telling question requires an elaborate conceptual framework to guide inquiries and to set those inquiries within the context of some field of study. Now, since junior high students do not encounter such far-reaching questions, and do not delve deeply within the conceptual framework of the scientific disciplines, the use of "telling question" was considered inappropriate to our needs for the project. For some time, the staff considered several other terms to identify the kind of question that is asked in laboratory exercises at the junior high level. At first, we thought that the term "good question" might accommodate our needs since it could distinguish between a question that led to a comprehensive inquiry and one that did not (a "bad question"). However, this was discarded when we realized that to use the term "good" was value-laden, and may be inappropriate for a knowledge inquiry.

Finally, the staff decided that "focus question" would be more specific in identifying the function of the inquiry. Our early work with students at Boynton Junior High School and Lansing Middle School suggested that the question should focus upon the events or objects that were to be observed in the inquiry, and also identify, either explicitly or implicitly, the concepts relevant to the laboratory exercise. We found it helpful, also, to move the focus question from the left-hand side into the center of the "V" since it was "central" to the inquiry and played a role in tying together the conceptual and methodological elements of the investigation.

Another problem arose when considering the terms "conceptual system" and "concepts." In our early attempts in the Ithaca junior high school, we discovered that students had a great deal of difficulty distinguishing between the two. Again, we tried several alternative terms, until we decided to adopt "principles" as the term that would occupy the space above concepts and below theory. As noted in the previous section, principles are propositions composed of two or more concepts, although not all propositions are principles.

Three sources of principles were also identified. Principles could come from the prior knowledge claims of some previous inquiry (empirical principles). Principles could also come from some theoretical model in the form of propositions (theoretical principles). These two types were grouped under the heading of "conceptual principles." The final type of principle was derived from the use of instrumentation and other record-making devices that are used in the laboratory. These were called "methodological principles," and they serve to guide record-making and record transformations.

Turning to the right-hand side of the "V", fewer modifications occurred as a result of our work with students and teachers. We felt that records and transformation would suffice for the kinds of investigations that students engaged in at the junior high level although we did find evidence that students did have difficulty knowing where these two terms fit along the "V".

Under "claims," we soon restricted ourselves to using only "knowledge claim." There were two reasons for eliminating "value claims." First, we were having (at that stage of the project) enough difficulty with teaching the "V" to junior high students, and thought that the introduction of a new set of ideas needed to clarify the meaning of "value claim" would only make matters more difficult. Second, and probably more important, at the beginning of the project there was a dispute about values clarification in a school district nearby. Now, although we recognized that there was a vast difference between our definition of "value claim" and how "values clarification" has been used (Raths, Harmin, and Simon, 1966), we felt that there might be some sort of backlash, a backlash that the project could ill-afford to encounter. Thus, for political reasons, this aspect of the "V" was deleted.

Considering in retrospect the important aspects of value claims in the sciences -- truth, elegance, practical application, and such -- it is regretable that this facet of the project could not be pursued. It is encouraged that, now having a firm basis for implementing the knowledge "V" in the classroom, this aspect of the "V" might be investigated in the future. It is considered an important and rich source of information about the sciences, though different than the content orientation that so often occupies teachers and students.

The term "epistemology" was also dropped in favor of the term "knowledge." Giving students and teachers such an unfamiliar work was not in keeping with the learning theory that formed the basis of the project. The concept label was inhibiting the learning of the meaning of that concept.

Finally, although we found no problem with using "conceptual side" and "methodological side," we offered the teachers the option of using the "thinking side" and the "doing side," respectively. Most teachers, though, used both groups of terms concurrently.

There were no changes in the use of the terms "events" and "objects." Given all this, the "Knowledge 'V'" evolved into the following structure (Figure VI.2). For a more comprehensive description of each of these terms and their definitions, refer to Section IV in Appendix I.

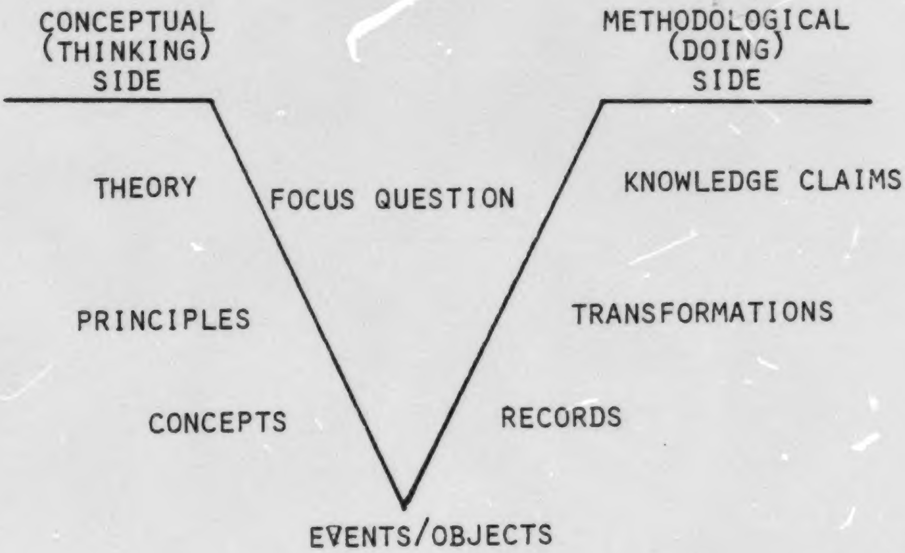
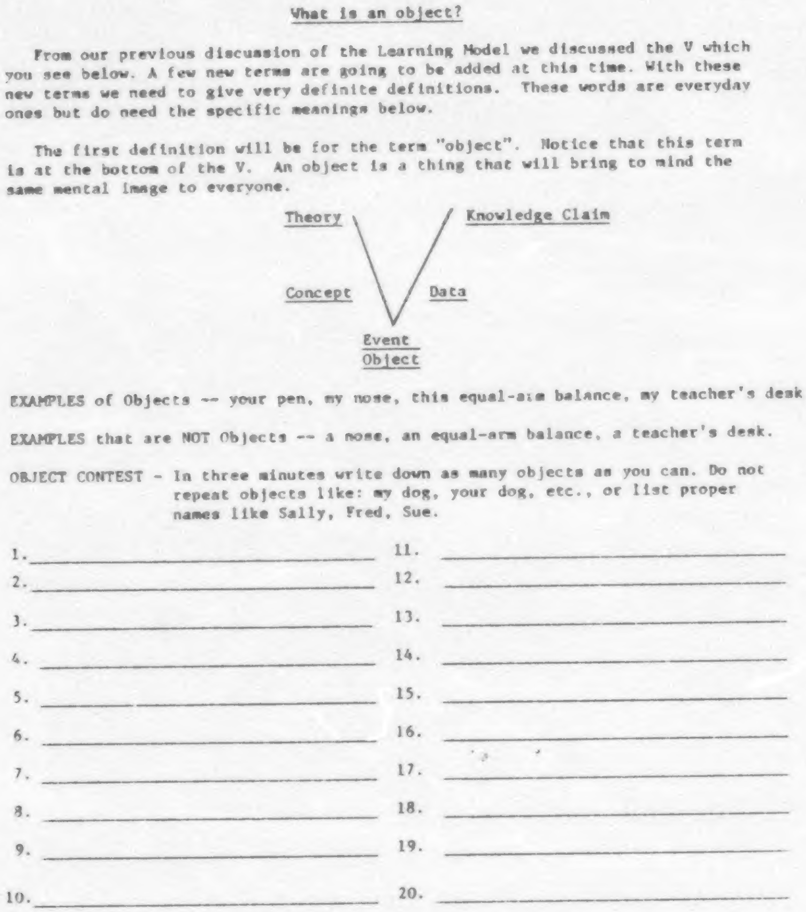

CONCEPTUAL
(THINKING)
SIDE
METHODOLOGICAL
(DOING)
SIDE
THEORY
FOCUS QUESTION
KNOWLEDGE CLAIMS
PRINCIPLES
TRANSFORMATIONS
CONCEPTS
RECORDS
EVENTS/OBJECTS

Figure VI.2. The Knowledge "V" as evolved in the "Learning How to Learn" Project.

Implementation of the Knowledge "V" - 1978-1979:

Development of strategies for introducing the knowledge "V" into the classroom proved to be a formidable task. Of course, our first contact with a school was done through the Ithaca City Schools, where we had one volunteer teacher from Boynton Junior High School. We were given permission to work with his class, but it was decided that at first we should begin to introduce the terms of the "V" with especially cooperative students. Thus, we asked for volunteers to meet with us after school at a time set aside for special activities.

These small group sessions, lasting a period of fifteen to twenty minutes, were begun in November, 1978. Since we did not have enough time during these "mini-lessons" to cover the entire "V," each successive period covered only one of the terms of the "V." To facilitate its introduction, worksheets, developed by the staff, were distributed to the small groups. Each of these sheets defined a term of the "V" and asked the students to identify examples. A sample worksheet for the term "object" is shown in Figure VI.3 below. Similar worksheets were devised for each of the other terms around the "V".



What is an object?

From our previous discussion of the Learning Model we discussed the V which you see below. A few new terms are going to be added at this time. With these new terms we need to give very definite definitions. These words are everyday ones but do need the specific meanings below.

The first definition will be for the term "object". Notice that this term is at the bottom of the V. An object is a thing that will bring to mind the same mental image to everyone.

EXAMPLES of Objects -- your pen, my nose, this equal-arm balance, my teacher's desk

EXAMPLES that are NOT Objects -- a nose, an equal-arm balance, a teacher's desk.

OBJECT CONTEST - In three minutes write down as many objects as you can. Do not repeat objects like: my dog, your dog, etc., or list proper names like Sally, Fred, Sue.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________
14. ____________________
15. ____________________
16. ____________________
17. ____________________
18. ____________________
19. ____________________
20. ____________________

Figure VI.3. Sample student worksheet for the term "objects". This and other worksheets for each term of the "V" were used with students during the introduction of the knowledge "V" in the Lansing Middle School, January-February, 1979.

After these initial trials with after-school groups, we found these approaches inadequate for two reasons. First, the terms of the "V" were being presented abstractly, i.e., out of context to the subject matter that the students were learning in class. No relation to their classwork or an inquiry was being established. Second, since the after-school sessions were on a volunteer basis, not all students showed up throughout the entire group of lessons. Thus, a problem of continuity arose. We asked the teacher to allow us class time to introduce the "V" in its entirety using a laboratory exercise involving breathing and pulse rate (see page II-2 of this report). The staff designed a "V" for the exercise based on how it was presented in the text, and proceeded to lay it out for the students after the exercise was completed. Although this was more in keeping with the trend that was to develop over the rest of the project, this particular laboratory exercise was seriously deficient in the conceptualizations about breathing and pulse rate. The students wondered why the large emphasis on the conceptual side of the "V" when, for this exercise, they recognized only a few concepts as relevant. Now, this of course was not true: there are a staggering number of concepts involved in the description of the breathing/pulse rate experiment, but most students knew so few of them that the use of the "V" seemed almost trivial. Through class discussions other concepts were introduced and a variety of knowledge claims were constructed.

Part of the difficulty experienced was that the "pulse rate" exercise was not written to highlight the relevant concepts and principles of the inquiry. It was decided that we should begin to design a laboratory exercise that would necessitate the inclusion of a number of concepts, shown in relation to each other as principles, and which was sufficiently difficult to warrant close examination of those concepts as precursors to the inquiry. We have found in research studies with college students (Chen, 1980; Buchweitz, 1981) that deficiencies in laboratory instructions lead to corresponding deficiencies in learning. Applying the "V" heuristic to analysis of laboratory instructions can detect deficiencies and can be used to remedy the problems.

We proceeded to design a laboratory experiment using the concept of digestion. Since human digestion is difficult to examine in vivo, we planned on using an alternative. With the cooperation of the Cornell Food Science Department, we were able to obtain samples of food from a slaughtered cow's alimentary canal. With these samples from the esophagus, first stomach, small intestine, and large intestine, a lab exercise was designed with the focus question, "What happens to the starch in grain as it is digested in the cow's digestive system?"

Using the iodine-starch test and the Benedict's solution-sugar test, we divided each class into four groups with each group responsible for testing the contents of one part of the digestive system for starch and sugar. The experiment took 1-1/2 periods to run, and the discussion where the "V" was used to "unpack" the exercise took almost one-half period. Given the unfavorable time that the experiment was run (two days before the Christmas vacation), and the students' limited exposure to the "V", the staff decided that this trial showed moderate success. It was realized, though, as a result of this attempt, that our staff could not become a substitute for the teacher and teach the learning strategies directly to the students. It was clear that we needed to use the existing curriculum and work with the teachers who would, in turn, introduce the strategies to the students.

Directly after the winter vacation, the volunteer teacher in Boynton announced that be would not be returning to the classroom after that year.

Since, by that time, it was clear that our project would continue into the next school year, and given that no other teachers in the Ithaca city schools had expressed interest in our project, we decided to pursue cooperation with other school districts.

Fortunately, around that time, contacts had already been established with an eighth grade science teacher in the Lansing Middle School. He was teaching the laboratory-oriented IPS Program, and we felt that this might be the optimal situation for introducing the "V". We scheduled some informal meetings with that teacher to instruct him as to the nature and use of the "V". After a few hours which included discussion of the nature of our project and its objectives, this teacher introduced the "V" to his IPS class. This class was composed of about twenty-two students who were considered above average in reading and mathematics, and for this reason were selected to take part in the IPS Program. Again, we used the worksheets to introduce the terms of the "V". Students completed the worksheets for homework, and then discussed them in class the next day, often relating the meanings of the terms to the laboratory exercises that they had been working on in class.

The "scientific method" vocabulary that had operated in the IPS Program was substituted with the terms of the knowledge "V". This reinforced the attention of the program away from the more methodological aspects of IPS toward the conceptual side of the "V" and the knowledge claims that had been accumulated during the first half of the year. In fact, at one point the participating teacher assigned individual students to review one or more of all the previous laboratory exercises, and to compile all the knowledge claims that were derived from them. The students were highly successful with this assignment, accumulating nearly forty claims. Now it was felt, the students had a working list of "empirical principles" that could be functional in any subsequent laboratory exercise. Students began to recognize that knowledge claims from one inquiry could become principles that guided future inquiries. They also recognized that little or no theory level had been utilized. This was encouraging to the staff, since it pointed out one of the major strengths of the "V" (and one of the major weaknesses of the IPS Program): the capacity to recognize how each of the "V" elements operates in an inquiry and how new knowledge is dependent on prior knowledge. This experience led in part to the section in the Teacher's Handbook which discusses sequencing of "V's". (See page V-18 in Appendix I.)

Another consequence of the "V" activities of the students was the clarity with which both they and the teacher saw the need for the broader explanatory power of a theory. As a result, the teacher's instructional plan was modified so that the theory unit (Chapter 8) was taught directly after unit five. This was done because the IPS Program reserves discussion of the major theoretical model (molecular kinetics) until after the empirical research has been completed. IPS exemplifies the Piagetian developmental psychology and the inductivistic philosophy of science which underlies the program, in contrast to our Ausubelian approach that places central focus on the acquisition and use of relevant concepts and a Toulmin philosophy that stresses the evolution of concepts (Novak, 1977b).

We continued in the Lansing Middle School throughout the Spring, 1979. As that teacher became more comfortable with the "V" strategy, the attention of the staff was directed toward the other two schools that were just then expressing some interest in our project. The one seventh grade teacher in Trumansburg was willing to adopt our ideas in one of her classes, and the one seventh grade teacher and one eighth grade teacher in the African Road Junior High School (Vestal) also were willing to explore incorporating the strategies into their respective curriculums.

Again, these three teachers were given the worksheets on the "V". They used them in their classes, but expressed confusion and lack of communication about the implementation of the "V" strategy. It was realized later that in order to implement this kind of program within the conventional school setting, given all the other pressures that accompany the teacher's day, more intensive training would be necessary. The staff soon recognized that we could not just hand the teacher the materials and "let them loose in the classroom." Rather, a firm and more complete orientation to the philosophical and psychological foundations of the project must be planned prior to the introduction of the materials into the classroom.

Not much progress was made with the "V" in Vestal in those few months of the 1978-1979 school year. Trumansburg did better, partly as a result of closer staff and teacher communication and geography. With the small, but encouraging, successes in Trumansburg and the information we obtained through the introduction of the "V" strategy in Lansing, plans were made for work in 1979-1980 to acquaint the teachers with the concepts underlying the knowledge "V".

Implementation - 1979-1980:

With the beginning of the new school year and the second year of the project, the staff geared up to implement the "V" in Trumansburg and Vestal. The teacher with whom we were working in Lansing decided to return to Cornell to pursue a masters degree and to become part of the project's research team. During the Summer of 1979, the staff devised knowledge "V's" for the standard laboratory exercises from the texts and laboratory manuals that the teachers would be using. It was also decided that classes would first be introduced to the learning activities (Appendix I, Section II) and then to concept mapping. In Trumansburg, the teacher decided not to introduce the structure of the "V" until after her students were familiar with its terms, each of which was incorporated into class discussions. The terms were only introduced as they related to the subject matter content that the students were doing in class. The structure of the "V" was later introduced when it was perceived that the students were ready to apply concepts to the interpretation of laboratory events. An early laboratory exercise served this purpose well.

In the first week of school, the students set up a "beef bouillon" experiment. The students were instructed to set up four test tubes, each with some bouillon in it. Two of the test tubes were left uncovered; the other two were covered. One covered and one uncovered were then placed in boiling water for some time to sterilize the medium. The remaining two were not sterilized. Students were to observe the test tubes daily and record any changes in the bouillon over a period of two weeks. During the two weeks, other laboratory exercises were conducted, and the terms of the "V" were introduced and used. When it came time to make conclusions (knowledge claims) about the beef bouillon experiment, the laboratory workbook required the students to make claims that were relevant to the question of what was needed for life to sustain itself -- concepts that the students had not learned! As the class discussed the lab, the students realized that they did not possess the proper conceptual framework to make the kinds of claims required. Enter, then, the need for the conceptual side of the "V". It was demonstrated very clearly that the lab exercise only "made sense" when the records that they had been keeping for the two weeks were seen in relation to the concepts of "life," "nutrients," "temperature," "growth," and a host of other concepts and principles. From that point on, throughout the school year, the students continued using the "V" for their laboratory exercises.

In Vestal, the procedure for introducing the "V" was different, and also delayed. Both teachers there had expressed some confusion and anxiousness about understanding and using the "V". They both asked that a member of the staff come down to teach the classes and the teachers how to use the "V". On two separate occasions, one of the staff members visited the classes on a day following a laboratory exercise.

In the eighth grade classes, the students had performed an exercise on the heat lost by iron washers to a given volume of water. One of the knowledge claims that was to be made dealt with how much heat was lost by the iron washers when placed in a volume of water. The students had computed the heat gained by the water by measuring the change in temperature and the mass of the water. (Since the specific heat of water is 1.0, that was not considered in the calculation.) With that calculation and value, the question of how much heat had been lost by the iron washers was posed. The staff member showed how this laboratory exercise would be represented on the "V". It was revealing to the students and teacher alike that the learners had not been exposed to the law of conservation of energy, an extremely important principle in the understanding of the exercise. Without it, no claim could have been made about the amount of exchanged heat.

This episode provided that teacher with what he considered the most salient feature of the "V": its ability to be used as an effective pre-teaching device that is employed to analyze a laboratory exercise prior to conducting it in the classroom. We have also found this to be true in our research program with college material (Chen, 1980).

A similar experience was conducted with the seventh grade teacher in Vestal with a laboratory exercise that dealt with the difference between onion cells and cheek cells, a classic exercise in junior high biology classes.

The students, having already discussed the parts of the cell, the functions of each, and the major propositions of the cell theory, were prepared conceptually for the laboratory exercise. Also, the students were sufficiently familiar with the methodological techniques of staining and microscopy.

As the class and the staff member were discussing the claims about the differences between onion and cheek cells, one student offered the claim that cheek cells contained vacuoles (since cheek cells were animal cells and all animal cells a priori must contain vacuoles). But based on the records that they collected, no vacuoles were noted in any of the cheek cells examined. This pointed up one of the limits of knowledge claims: they must be consistent with the records and transformations made. If the inquiry had the purpose of determining if cheek cells have vacuoles, then the claim for this exercise must be "no." But that claim was conditional, given the limits of the person doing the observation and the instrument used to make the records. This was discussed with the class. The problem was tentatively resolved with the recommendation that perhaps a better microscope may indicate the presence of vacuoles in cheek cells. However, for the instruments and records that were part of the laboratory exercise, no claim could be made about the presence or absence of vacuoles in these cells. (Both the "V's" for the heat loss experiment and the onion-cheek cell experiments are reproduced in Appendix I, pages IV-2 and IV-3).

Evaluation:

From November, 1978 through June, 1979, the feedback from school tryouts of our "learning to learn" strategies provided us with valuable formative evaluation data. Each failure and each success in instructional approach came through loud and clear with statements such as, "What do you mean by an event?";

or "Why isn't rain an event instead of a concept?"; or "I don't see how to show a dissection exercise on a 'V' map." or "Wow, this really helps me to see what's going on in this experiment!" In addition to innumerable anecdotal comments such as these, we also conducted more systematic formative evaluation, some of which is described in the following pages.

Summative issues also were addressed, but primarily during the second year of the project. In essence, we wanted to determine several related issues of using the "V" for laboratory exercises and learning in general. These concerns have been divided into three specific questions, and each of them with their accompanying data will be discussed below.

Can students identify, define, and pick out examples of the terms of the "V"?

This was the easiest aspect of evaluation of the "V" since it only required that students be able to place the terms of the "V" in their correct positions, define each of the terms, and, using past experiences in the lab, provide examples of each of the terms. A two-page pencil and paper instrument was then devised to reflect this task. We began with a trial run in Lansing in April, 1979 and followed with another tryout in Trumansburg in October, 1979.

Although the essence of the instrument was felt to work quite nicely, the structure left much to be desired. Students had to write each of the terms three times, definitions were separated from examples, and the examples were to be drawn by students from past laboratory experiences. A major revision of the instrument was done during the Winter, 1979-80.

A series of clinical interviews were conducted in Trumansburg in Februrary, 1980 to evaluate the new instrument. Eleven students were asked to label a blank "V", give the definitions of each of the terms, and identify examples of each of the parts. Students were also asked questions about the responses they made. Results from this preliminary assessment are reported in Figure VI.4 a-c. Based on the recommendations of the staff and one participating teacher, the labelling task and the defining task were grouped together. Also, instead of having students remember examples from previous laboratory experiments, we provided a copy of a completed laboratory exercise that the student had already done in class. A copy of this instrument, with two laboratory exercises as examples, can be found in Appendix I, pages V-10 and V-11.

Figure VI.4. Percentage scores on the "V" interviews, conducted in Trumansburg, February, 1980. (N = 11) Percentage score computed from student's score divided by a maximum score, and multiplied by 100. KC = knowledge claim; Tr = transformation; R = records; O = objects; E = event; C = concepts; P = principles; Th = theory; FQ = focus question; To = total score for that question.

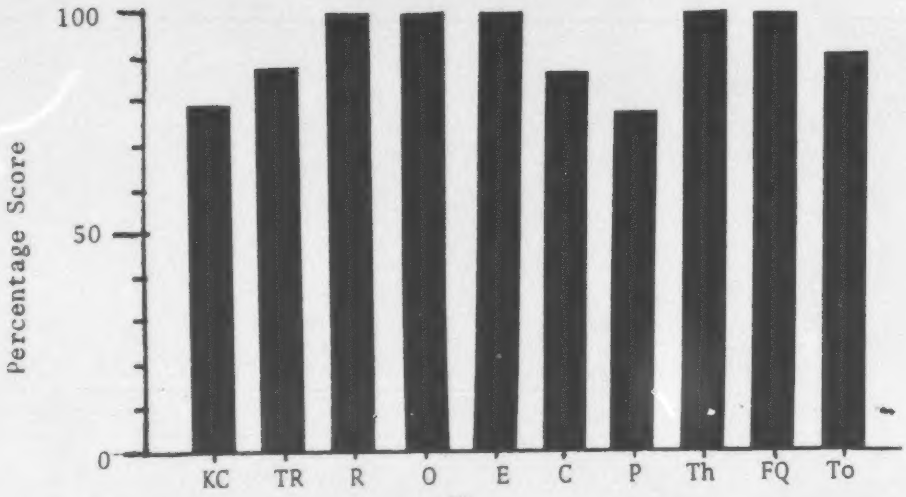


Figure VI.4a. Labeling parts of the "V".

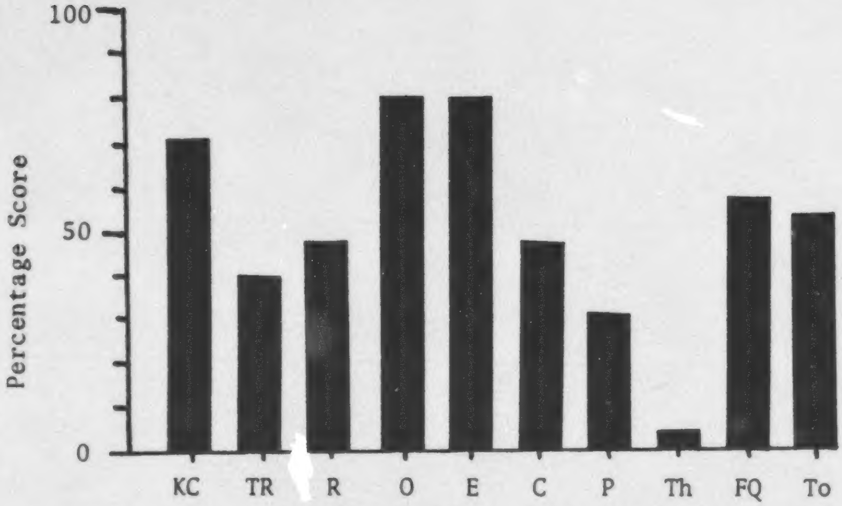


Figure VI.4b. Defining terms of the "V".

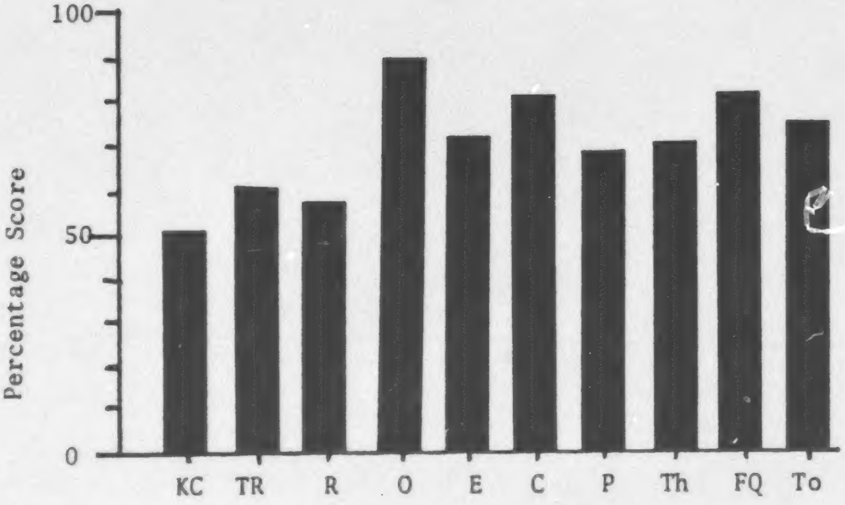


Figure VI.4c. Picking out examples of terms of the "V".

Examination of even these very preliminary results provide some clues as to the familiarity of the student with the "V" and where the emphasis is relative to instruction about the "V". First, Figure VI.4a indicates that students can position most of the terms in their correct places around the "V", but as indicated by Figure VI.4b, their ability to define each term of the "V" was not encouraging. Indeed, a very small percentage of students could give an adequate definition of "theory." This could be due to the fact that the teacher in Trumansburg had not taught the students a variety of theories, but concentrated mainly on the cell theory and the theory of natural selection. Thus, the students were not privy to the range, function, and structure of a theoretical model. On picking out examples (Figure VI.4c) the students did much better. There are indications that, although students could not provide comprehensive definitions of the terms as shown in Figure VI.4b, they did have enough operating definitions for several of the terms to be able to recognize examples of most of these terms within the context of a given laboratory exercise. Only "knowledge claim," "transformation," and "record" provided some difficulty. But that might have been the fault of the instrument used: examination of the instrument on page V-11 in Appendix I (bean pod experiment) shows that the records are embedded in two types of transformations, the table and the graph. Students did have some trouble distinguishing the records (the actual number of bean in each of the pods) from the transformations (table and figure for frequency distribution).

From the results of this preliminary assessment, the staff conducted a similar assessment within a whole class setting, thereby collecting records for all the students at one time. This was done in Trumansburg, using a laboratory exercise on bean seeds, and with the Vestal eighth grade, using a laboratory exercise on heat loss. The data for these two groups are reported in Table VI.1 below. Included also is a description of how the instrument was marked. The Vestal seventh grade group was not assessed because they had had only limited exposure to and instruction in the use of the "V".

Table VI.1. Results for assessment of identifying (Question #1), defining (#2), and picking out examples (#3) of terms of the "V" for Trumansburg (April, 1980) and Vestal-8th (May, 1980). From Knowledge Claim (KC) through Focus Question (FQ) there was a maximum of two points for each; Total Score (To) had a maximum of eighteen.

	Trumansburg (April)			Vestal (May)		
	QUESTIONS			QUESTIONS		
	#1	#2	#3	#1	#2	#3
Knowledge Claim	1.97	1.89	1.70	1.20	1.48	1.57
Transformation	1.97	1.57	1.81	1.79	1.48	1.42
Records	2.00	1.59	1.67	1.69	1.44	1.49
Objects	1.97	1.90	1.91	1.26	1.29	1.20
Events	2.00	1.94	1.92	1.51	1.61	1.39
Concepts	1.97	1.83	1.23	1.90	1.43	1.46
Principles	1.99	1.45	0.79	1.83	0.90	1.13
Theory	2.00	0.06	0.47	1.95	0.55	1.49
Focus Question	2.00	1.92	1.89	1.26	1.73	1.79
Total Score	17.87	14.23	13.30	14.39	11.92	12.90

In essence, each of the three questions of this assessment constituted a separate instrument, each with its own objective of determining how familiar the students were with the knowledge "V".

The assessment was graded on the basis of two points maximum for each part of the question. Thus, the proper definition of "theory" was awarded two points. If the student in writing a definition or example of a particular term did not have a totally correct answer, but one that provided an indication that the student "was on the right track," one point was given. If the answer was totally wrong, no points were awarded.

A comparison of the performances of the Trumansburg group and the Vestal group should be done with the utmost caution. There were several factors present that might affect the validity of any generalization between the two groups. First, the Trumansburg group received a greater amount of instructi in the "V", having used it since the beginning of the year. The Vestal group had only been using it for five months. Second, although the instruments were identical for Questions #1 and #2, the laboratory exercises used from which the students picked out examples (Question #3) were different. There is no way, that we know, of comparing the relative difficulties of these two laboratory exercises. Third, the assessments at both schools were administered by staff members. Although we had made several trips to Vestal to observe classes and interview students, the amount of time directly in contact with the students in Trumansburg far exceeded the time directly involved with the students in Vestal. Thus, the Vestal students might have been a little nervous being evaluated by the "Cornell people." The Trumansburg group, by that time, were quite familiar and comfortable with the constant visitations to their classroom. However, the Vestal eighth grade students were on the average on year older tha the Trumansburg seventh grade students.

In light of these cautions, however, there are some interesting comparisons that can be established between the two groups. Trumansburg preformed better on the average for the total scores for each question. This might indicate that there is a factor of "time on task" which is important to the mastery of the knowledge "V". To individual questions, although both groups were comparable in identifying "theory" on the "V" (2.00 for Trumansburg; 1.95 for Vestal), Vestal did much better at defining and picking out examples of the theory in the given laboratory exercise (0.55 and 1.49 for questions #2 and #3 for Vestal; 0.06 and 0.47 for Trumansburg). Since the eighth grade teacher in Vestal stressed to a great degree the importance of the theory in scientific inquiry, we would expect this finding. As mentioned earlier, the teacher in Trumansburg did not stress theory as much. Further, in the laboratory exercise given the Trumansburg students the theory that was provided was written as "natural selection." The students should have known that, but were probably more familiar with the term "theory of evolution." This may account for the comparatively low score in that question.

Can students use of the knowledge "V" for laboratory exercises they perform in class?

To answer this question required two separate activities during the course of the second year of the project. First, arrangements had to be made to acquire and accumulate a large sampling of laboratory exercises put on the "V". This was easiest for our group in Trumansburg since they had used the "V" from the beginning of the year and because a staff member worked closely with that teacher which took some responsibility off the teacher.

The second major activity involved with answering this question dealt with the creation of a scaling device to measure students' ability to put a laboratory exercise on the "V". During the second of our consultants' meetings (July, 1979), it was recommended that we identify some sort of ordinal scaling procedure for assessing the "V's" that students turn in. A preliminary scaling procedure, based on analysis of previously constructed "V's", was developed in August, 1979.

The nine terms of the "V" were grouped into five general categories since some of the terms depended closely upon related terms. Thus, "theory," "principles," and "concepts" were grouped together; "objects" and "events" were grouped together; and "records" and "transformations" were grouped together. "Focus question" and "knowledge claim" were thought to stand independent of, at least for assessment purposes, the other parts of the "V".

The scaling for each general category began with zero, indicating that nothing in that group was identified by the student. Next, an optimum representation of that category was constructed, specifying the criteria needed to represent that optimum. These were not immediately assigned a numerical value. For instance, the focus question was identified to be optimum if it contained the key concepts to be used in the inquiry and suggested the major event and/or relevant objects. From that optimum case, varying degrees of "completeness" were then added into the scale for focus question. The number value for the optimum case would thus depend upon the number of specifically identified levels for that category, beginning with zero ascending to the optimum value.

Scoring procedures for the "focus question" are shown in Table VI.2. Examples of two laboratory exercises, marked with the criteria are shown in

Figures VI.5a - b. A complete listing of the criteria for assessing student-constructed "V's" can be found in Appendix I, page V-14; other examples of "marked" "V's" can also be found in that Appendix, pages V-15-17.

Table VI.2. Development and examples for criteria for assessing the focus question on student-constructed "V's".

NUMBER VALUE	IDENTIFYING CHARACTERISTIC OF THE FOCUS QUESTION	SAMPLE (from a lab on the electrolysis of water)
0	no focus questions is identified.	(student writes nothing)
1	a question is written, but does not focus upon the objects and the major event OR the conceptual side of the "V".	"What's in water?"
2	a focus question is identified; includes concepts, but does not suggest objects or the major event OR the wrong objects and events are identified in relation to the rest of the lab.	"What elements are in water?"
3	a clear focus question is identified; includes concepts to be used and suggests the major event and accompanying objects.	"What elements can be identified through the decomposition of water using the Hoffman apparatus?"

These criteria went through at least six revisions over the five month period from August through December, 1979. Revisions were based on field-testing of the criteria against sample "V's" that the students were completing in Trumansburg. These criteria were used, then, to assess the student-constructed "V's" which formed the basis of the records that the project collected from October through May, 1979-80, in Trumansburg.

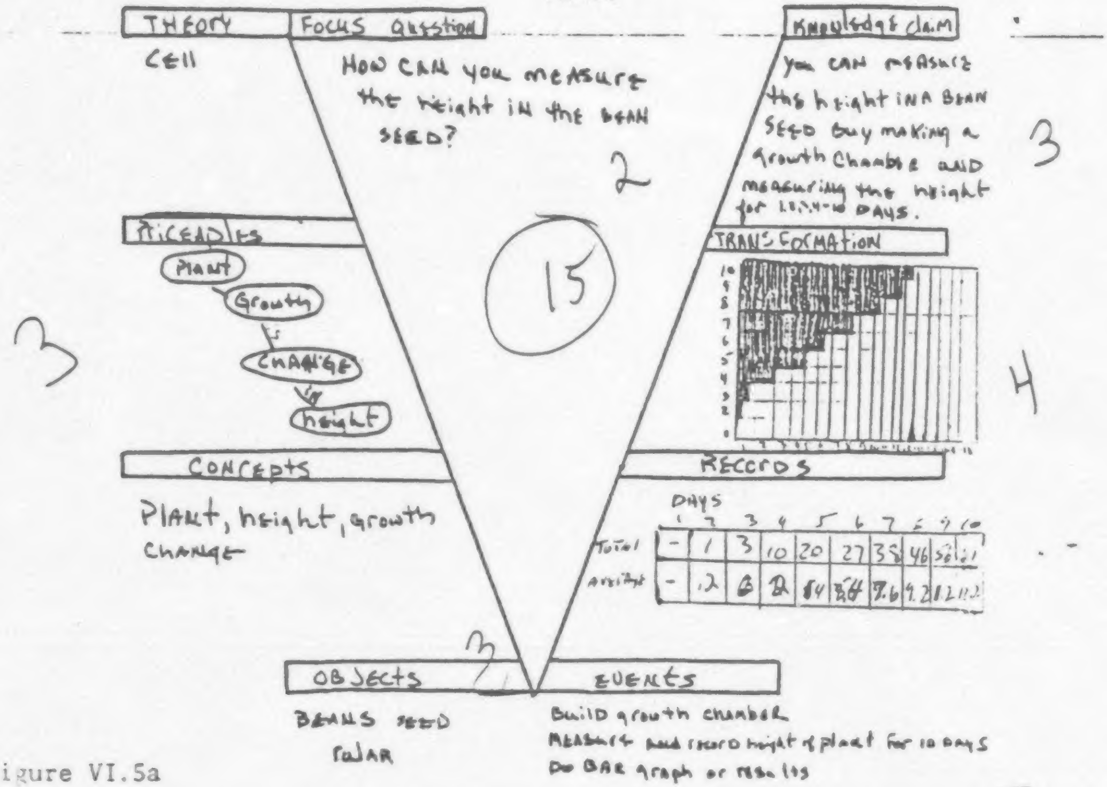

THEORY
CELL
FOCUS QUESTION
HOW CAN YOU MEASURE the height IN the BEAN SEED?
2
Knowledge claim
You CAN MEASURE the height IN A BEAN SEED buy making a growth Chamber AND measuring the height for [illegible] DAYS.
3
PRINCIPLES
Plant
Growth
CHANGE
height
3
15
TRANSFORMATION
4
CONCEPTS
Plant, height, growth
change
RECORDS
DAYS
1 2 3 4 5 6 7 8 9 10
Total - 1 3 10 20 27 38 46 56 61
Average - .2 .6 2 .4 .4 7.6 9.2 11.2 11.2
3
OBJECTS
BEANS SEED
ruler
EVENTS
Build growth chamber
Measure and record height of plant for 10 DAYS
Do BAR graph or results

Figure VI.5a

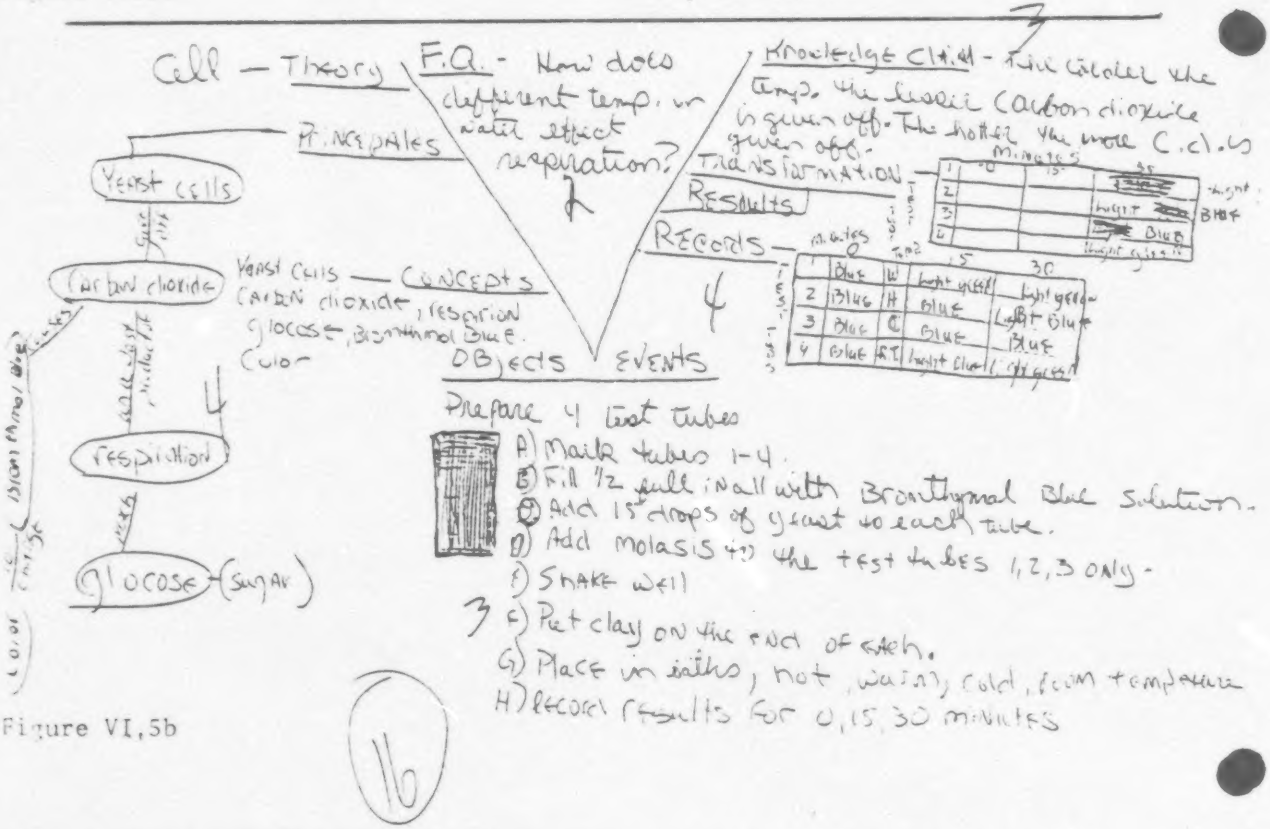

Cell — Theory
F.Q. - How does different temp. in water effect respiration?
2
Knowledge Claim - The colder the temp. the lesser carbon dioxide is given off. The hotter the more C.d. is given off.
7
PRINCIPLES
TRANSFORMATION
RESULTS
Minutes
0 15 30
Test
1 2 3 4
light
Blue
light green
RECORDS
Minutes
0 15 30
1 Blue W light green light green
2 Blue H Blue Light Blue
3 Blue C Blue Blue
4 Blue R.T. light Blue light green
4
Yeast cells
Carbon dioxide
respiration
Glucose (sugar)
4
Yeast cells — CONCEPTS
carbon dioxide, respiration
glucose, Bromthymol Blue
Color
OBJECTS
EVENTS
Prepare 4 test tubes
A) Mark tubes 1-4.
B) Fill 1/2 full in all with Bromthymol Blue solution.
C) Add 15 drops of yeast to each tube.
D) Add molasis to the test tubes 1, 2, 3 only -
E) Shake well
F) Put clay on the end of each.
G) Place in baths, hot, warm, cold, room temperature
H) Record results for 0, 15, 30 minutes
3
16

Figure VI,5b

Figure VI.5. Two examples of "V" maps produced by seventh grade science students showing scoring applied by project staff. (Trumansburg, 1979-1980).

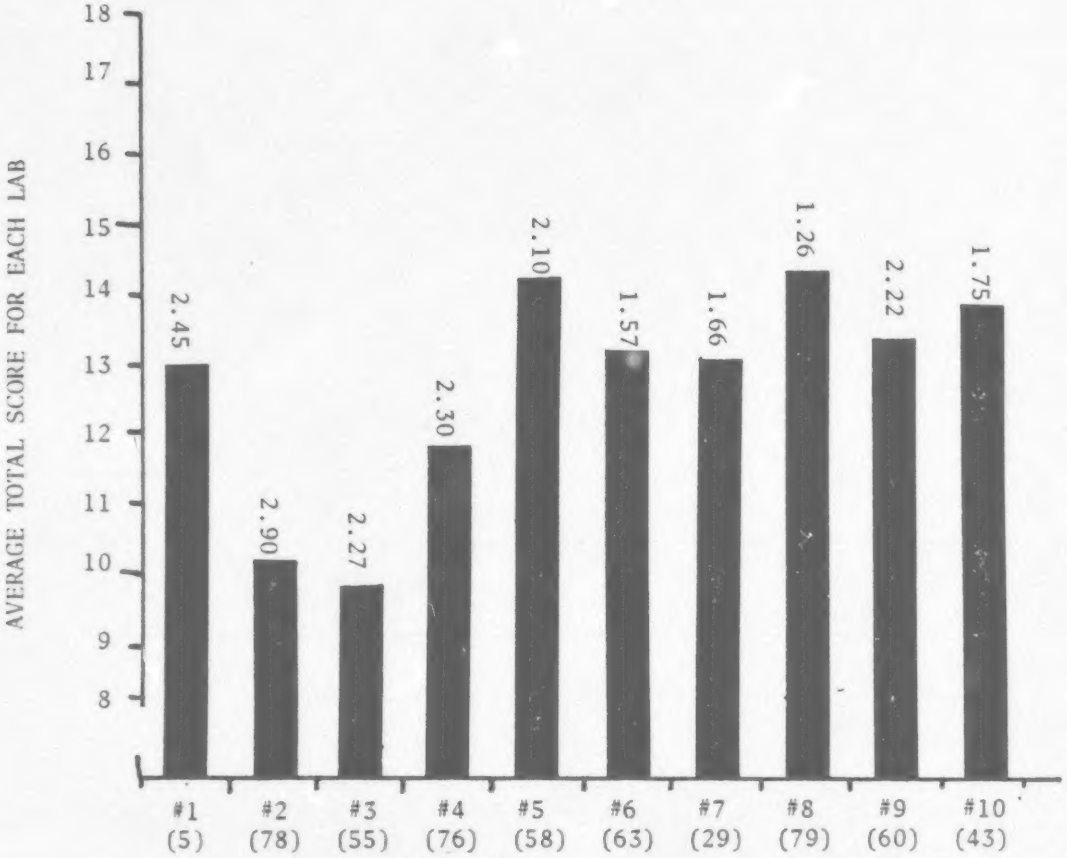
An analysis of the rating scale for assessing student-constructed "V's" was completed and is reported in the final part of this section.

Student-constructed "V's" were collected and assessed for ten representative laboratory exercises from October, 1979 through May, 1980 in Trumansburg. The results of the analysis of these "V's" are given below in Table VI.3 and Figures VI.6 and VI.7.

Table VI.3. Results of ten student-constructed "V's" using the criteria to assess how well students use the "V". Since Laboratory #1 had such a small sample number (5), this will be disregarded in the analysis. Identification of the titles of each laboratory exercise appears in the key from Figure VI.6. Number in parentheses indicates sample size for that particular exercise,

LABORATORY EXERCISES ASSESSED

Criteria Category	Maximum Value	#1 (5)	#2 (78)	#3 (55)	#4 (76)	#5 (58)	#6 (63)	#7 (29)	#8 (79)	#9 (60)	#10 (43)
Focus Question	3	3.00	1.77	1.92	2.42	2.74	2.27	2.34	2.91	2.12	2.33
Objects/ Events	3	2.40	1.69	2.24	1.51	2.12	2.19	2.41	2.35	2.88	2.72
Theory/Principles/Concepts	4	1.80	1.54	1.71	2.60	3.09	2.89	2.72	2.69	2.38	3.18
Records/Transformations	4	2.60	3.28	2.33	3.28	3.55	3.32	3.27	3.90	3.45	3.14
Knowledge Claims	4	3.20	1.92	1.51	2.04	2.57	2.52	2.37	2.33	2.43	2.58
Total Score	18	13.0	10.20	9.71	11.86	14.07	13.19	13.14	14.19	13.27	13.95
Standard Deviation for Total Score	---	2.45	2.90	2.27	2.30	2.10	1.57	1.66	1.26	2.22	1.75



NUMBER OF LABORATORY EXERCISES USED IN THE ASSESSMENT OF STUDENT-CONSTRUCTED "V's". SAMPLE NUMBER IN PARENTHESES.

Figure VI.6. Average total score for the ten representative laboratory exercises placed on the "V". Numbers above each bar represent the standard deviations for the total scores for each laboratory exercise.

Key to Laboratory Identification; number in parentheses is the week in the academic year in which the laboratory was taught.

Lab #1 - (2) Hot Liver	Lab #6 (15) - Perch Dissection
Lab #2 - (4) Lima Beans	Lab #7 (17) - Pulse Rate/Exercise
Lab #3 - (6) Protection Coloration	Lab #8 (24) - Blood Pressure
Lab #4 - (10) Am I Made of These?	Lab #9 (30) - Saliva Analysis
Lab #5 - (13) Earthworm Dissection	Lab #10 (32) - Seed Growth

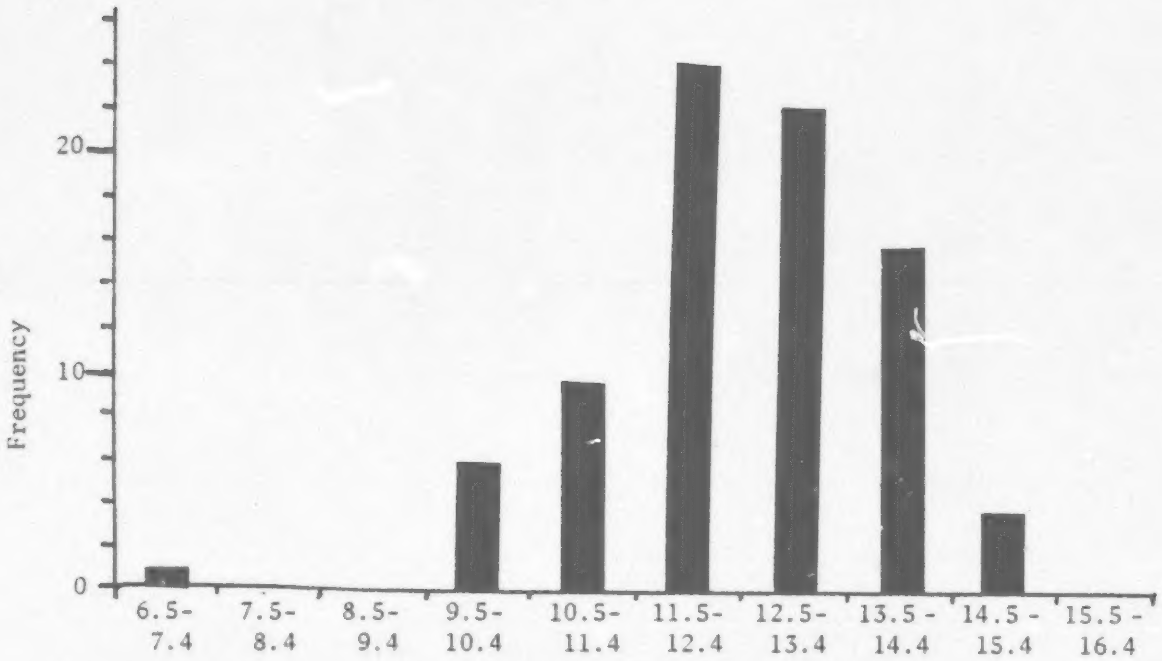


Figure VI.7. Frequency distribution of averages of all labs represented on the "V" for eighty-three students at Trumansburg, September, 1979 through May, 1980. Two students did not complete any "V's"; the one student within the range of 6.5-7.4 turned in only one laboratory "V".

Although a more thorough quantitative analysis appears in Section IX, some analysis of these data should be done prior to moving on in this report. From the information gathered thus far, it is reasonable to conclude that junior high students can use the "V" to represent what is occurring in their laboratory experiments. From Figure VI.6, we can see that the students appear to get better as their exposure and familiarity with the strategy increases. But again, the use of this kind of comparison is done with a certain amount of caution. The laboratory exercises represented in Figure VI.6 may not all be of equal difficulty, and therefore there is a problem of validity of stating that students did improve over time. Perhaps only their lab exercises became easier or they finally got used to junior high science. However, if the standard deviations among all those labs depicted in the graph are examined, a trend from a large standard deviation to a small standard deviation occurs. This might indicate that the students are becoming more familiar with the strategy and are able, generally, to use the strategy effectively enough to place comparatively high on the scale. Examination of Table VI.3 furthers demonstrates this "levelling off" of students' grades in each of the five general criteria categories.

It should be noted that Laboratory Exercise #1 shows a strikingly high average total score in comparison to the other initial laboratories. But because the N-number (5) is so small that can be attributed to too small a sample to make any conclusive statement.

The performance indicated in Figure VI.7 shows a clustering of "V"-map scores around twelve. Using a baseline of eighteen, this would represent an average performance of around 67%. However, the data in Table VI.3 show that students are limited in their success on "theories and principles" and this may be more a curriculum failure: little theory or basic principles are presented in junior high school science. Therefore, a more realistic baseline score would be 15 or 16, and the average student would thus show a "mastery" level of some 75-80%. Furthermore, students would often write the proper concepts, but be unable to extract from those concepts the proper principles and theory. Indeed, students often mistakenly identified the "cell theory" when "natural selection" was the theory in operation. Also, if cell theory was used, no conceptual principles were written that resembled the propositions of the cell theory.

Our experience over the entire year with these "V's" and their use in Trumansburg has led to some modification of the criteria that should be mentioned. In addition to having the comprehensive form of the criteria going through at least six revisions over the course of six months, the staff thought it fruitful as well to devise a list of more general, less rigorous criteria which could be used as an alternative by the classroom teacher. The simplified rating scale provides the teacher with a "ballpark" view of the "V" maps that students complete. It could be used at the early stages of using the "V", while students are just beginning to become familiar with the new terminology, or they could replace altogether the more comprehensive form. This, of course, would depend upon the needs of the class as assessed by the individual teacher. Both students and teachers find that the scoring criteria are also instructive as to how to construct good "V's", so these should be made available to all parties involved. This more general list of criteria for assessing student-constructed "V's" can be found in Appendix I, page V-13.

Another modification of these criteria actually came from some students who saw that there was a great similarity between the left-hand side of the "V" with its hierarchy and general to specific rule and the concept maps that they had been preparing from their textbooks. The students' suggestion that they substitute a concept map for that left-hand side was thought to be a remarkable insight for these students! The criteria for assessing the conceptual side of the "V" did not change in any way, but we were aware that there was more than one way to represent that left-hand side.

Do students change their method of "attack skills" as a result of exposure to the "V"?

This is one of the question that we attempted to answer very late in the project, but because of time and lack of resources (the staff was concentrating on accumulating all the other records), this line of research was not pursued. Although this could be a potentially powerful aspect of the teaching and learning of the "V" strategy, when our staff conducted some preliminary interviews in this direction we found no significant results.

The idea to evaluate this aspect of the use of the "V" actually came from some students who had participated in an informal interview about concept mapping and the "V". The students were given a hypothetical situation: "You are given a laboratory exercise that another student has completed. You look at his/her knowledge claims, and realize that they are wrong. Where would you look first to find where the student went wrong?" From the four students at the session, we received answers of, "look at the focus question," "look at the concepts and principles that she/he used?" and "look at the objects and events of the lab." None of the students identified the right-hand side of the "V" as the initial source of the problem. Since one of our objectives in the project was to have learners conceptualize better about inquiry events, we saw this as an indication that they might have changed their approach of attack skills and were beginning to conceptualize better about the events that they witnessed in the laboratory.

From this, a clinical interview involving both instructed and uninstructed students was designed. Using content material from the physical sciences, material that both groups had had, we devised a presentation that reported that someone was able to get more work out of a machine than was put into it, clearly a violation of the law of conservation of energy. Eighteen students were interviewed: ten instructed and eight uninstructed. While the results, as mentioned, are certainly not conclusive, more instructed students looked for the mistake among the concepts and principles than did the uninstructed group.

Although we did not have the resources to pursue this more definitively, the results could suggest that students might be able to make significant changes in their conceptualizations about the discipline of science and the role that concepts play in the creation of knowledge. However, greater exposure to, and use of, the "V" are indicated before learners could begin to show significant shifts in the desired direction. We should not expect substantive transfer of "V"-type reasoning to all problems with a limited exposure to the strategies in only one class for a segment of one school year.

As with concept mapping, opportunities were designed to determine the degree of students' understanding of the "V". In addition to evaluation of "V" maps described above, students' reactions and feelings about the "V" were solicited during informal interviews conducted with groups of students toward the end of the project (April, 1980). The following comments were made during these sessions. Since several students might be answering the same question, they are represented on separate lines. If the sentences are in succession the same student is answering. As before, the interviewer's questions are in capital letters; the interviewees' answers are in lower case.

The first question dealt with the use of the "V" to determine what a laboratory exercise was all about.

IF SOMEONE SHOWED YOU A LABORATORY THEY WROTE ON A "V", COULD YOU FIND OUT IMMEDIATELY WHAT THE LAB WAS ABOUT?

Yeah.

Look to the concepts, maybe.

First of all, I'd look at the focus question; see what they're trying to do.

[WHAT WOULD YOU GO TO THE CONCEPTS FOR?]

Information.

Yeah, what organs [students were discussing a lab on human physiology] they're using and all that.

What they had known before.

WHAT ELSE WOULD YOU LOOK AT?

Probably the principles to find out ... like, they got all these concepts and they put them together, and you can understand it with the principles.

Yeah, how the concepts work.

The objects and events, 'cause you have to know what they were using and what they did with [them].

... [I]f they did a concept map for the principle[s], I'd go there first.

In another session, students gave these answers to the same initial questi

Look at the focus question.

Look at the focus question. Then I'd probably look at the objects and events so that you know what you need. And you know what to do.

Knowledge claims to see what the question means.

SO YOU WOULD LOOK AT THE LEFT SIDE FIRST? OR WOULD YOU LOOK AT THE RIGHT SIDE?

The left.

IS THAT A PERSONAL PREFERENCE? WHY DON'T YOU TELL US WHY YOU WOULD LOOK AT THE LEFT?

[B]ecause if you're going to do the experiment with the "V" you have to see what you need first, and look at what you have to do. Then you look at the concepts that you have to know.

WHERE DO YOU START WITH THE"V"?

Well, you start with the -- you try to figure out a good focus question.

DO ALL OF YOU START THERE? WITH THE FOCUS QUESTION?

Not me. I start with the concepts.

YOU START WITH THE CONCEPTS?

I write down the concepts before anything else.

WHAT DO YOU DO AFTER YOU DO THE CONCEPTS?

Then either I do the objects and events, or I do the focus question. I probably *[would] do the focus question 'cause I can't do the events without the focus question.*

IF YOU WERE TO LOOK AT SOMEONE ELSE'S "V", WHAT PART WOULD YOU LOOK AT FIRST?

I'd probably look at the problem first, to see what they were doing.

I'd look at two things probably. I'd look at the records [and the] conclusions, because that's to see if that goes along with what the problem is.

I'd look at the event, because you have to see what they are going to be doing first.

I wouldn't go with [records], I'd look at the ... principles; the other things you'd like to know before you can do an activity.

Well, I think you should go to the theory first because in order to know the theory you have to know the principles, and the principles come out of the theory ... like the kinetic motion theory that we did. You know how you had to know that molecules were always moving.

But you have to know what "molecules" are.

What if you don't know what "kinetic" means?

Look it up!

This last group of quotes from students was an attempt to determine how well the "V" worked for them. Although they indicate a mixed reaction, they seem to point up the major confusion with working with the "V" within the subject matter content area. They have not been able, to some degree, to rise above the "V" to more clearly see the meanings embedded within the concepts of that subject matter.

YOU THINK THE "V" IS LOUSY? HOW COME?

It doesn't work. It doesn't give enough detail.

Yes, I thought the "V" was alot harder than the concept map[ping].

You have to put down the concepts and principles, but what do you put down for your concepts?

DO YOU SEE ANY USE FOR IT [THE "V"]?

Yeah, because then you can just look at it and you can get all the stuff you need.

Also, it shows what you did, how it turned out and everything.

Like in the records: to know what you did, you just look back and you know you did.

WHAT DOES THE RIGHT HAND SIDE OF THE "V" HAVE TO DO WITH THE LEFT HAND SIDE?

Well, first you have to have a left hand side in order to do the right, because the left hand side tells you ... what you have to know. And the right hand side tells you how to do it, and how to end it.

Well, the left hand side stuff [is what] you already know, and you use that stuff on the left hand side [to] figure out the information on the right hand side.

The teachers participating with our project were also asked about their impressions of the "V" and its applicability to the classroom. They were questioned about its advantages and disadvantages, and generally about how difficult it was to implement into the classroom.

The various uses of the "V" is evidenced in the discussion with the teachers. In this first quote, the teacher alludes to the "V's" ability to be used as a planning and diagnostic device.

... We take so much for granted that there's alot of kids that don't even have these basic concepts.... [Y]et you're talking about principles automatically and even a theory, ... and yet there's a kid down here who really never did understand [one particular concept]. [M]aybe that kids needs some extra help, or maybe you'd better stop a minute if four or five or six kids in the class really don't know [that concept].... He may know six out of seven [concepts], but that seventh one may be a real key.

Again, the "V" as a diagnostic tool is shown in the following quotes. Related to that is the function where the "V" specifies for the teacher and the student the more salient features of the laboratory inquiry.

... So having them put down all that stuff was helpful to me, because I could see, "Hey, this kid doesn't see or understand the differences [among] [concept A] and [concept B] or [concept C]," and that was very important for that lab.

... On the "V" you're listing materials and equipment and observations [just like] you would be doing [for] a lab report, but you're taking the next step of reminding yourself of things that you learned before. And alot of kids don't take the time to remember what they learned before.

Also, by its very nature, the "V" focuses the attention of the inquiry toward the objects and events, thereby constantly reminding the student what the laboratory exercise was all about.

You can ask four or five different kids in the same class what we did in a lab, and, you know, those kids are not going to agree on what we did.... When we do the objects and events on our "V",... if focuses them in on what they actually did in class.

Teachers also expressed some of the disadvantages of using the "V". Generally, they reflect the impression that using the "V" can become busywork or that the "V" is not always necessary.

I feel you don't have to have the kids fill them out all the time. ... I find that sometimes it takes up a little more time than I want to. ... [S]ome of the kids think that they're doing double work when they have to do the "V" after they've already done the lab and answered all the questions.

The difficulty of the "V" as "double work" can be alleviated by the teacher substituting the "V" for the laboratory report. The actual structure of the "V" is not important: it must be remembered that it is a heuristic that is used to represent the roles that our conceptualizations and methodologies play in any inquiry. Thus, the traditional laboratory report can be re-structured to accommodate the two roles of conceptualizations and methodologies. This was never fully realized by the teachers, but it appears clearly a staff's mistake because we wanted to see if students could use "V"-mapping.

Finally, the teachers were asked how difficult it was to implement the "V" into their curriculum. Aside from some initial anxiousness, the implementation was not difficult.

It wasn't difficult at all after I got the informational booklet deciphered (early version of the project's handbook).... It was easier for me to see a "V" already done.

> *Well, in the very beginning when I had a hard time realizing how I was going to present it to the kids, that was difficult. I would say that you [a staff member] helped iron out any problems [when] you had come down and gone through [a class, using the "V"].*

Caveats regarding the introduction and use of the knowledge "V":

Again, a listing of some of the shortcomings of our project might prevent the duplication of the same mistakes in a replication study. In addition to these, there are some others that thread through the entire preceding description.

1. Don't present the terms of the "V" out of context. That is, always use the terms relative to the content material that is being covered in class. For example, "What is the record of this experiment?" or "What is the major event of this phenomenon?" or "What principles are operating in this inquiry?"
2. The "V" structure itself could probably be dropped after the students have become familiar enough with the strategy. This could eliminate the "busywork" problem identified by the participating teachers. Lab exercises could also be written by the teacher using the "V" as an outline.
3. Encourage students to construct concept maps for the left-hand sides of the "V's". However, it is important to remember that these concept maps should be comprehensive, i.e., include the most relevant concepts, indicate principles, and have the theory as the superordinate concept at the top.
4. Related to #3, the theory identified at the upper left of the "V" is meaningless unless the student identifies at least one of the major

propositions in the principles section. For instance, it is not enough just to write "natural selection" in the theory slot without showing how "overproduction of offspring," "limits of food and space," and other principles of that theory relate to the concepts and event of the inquiry. Obviously, the mere writing of a name for a theory without showing its meaning in relation to the rest of the inquiry is an example of rote learning.

5. It is not enough to provide a classroom teacher with the teacher's handbook and some simple instructions and then let them try the strategies in their classes. A comprehensive, though moderately short, in-service training workshop should be mandatory. The major theoretical foundations of the "Learning How to Learn" Project call upon concepts and principles of learning theory and epistemology to suggest new perspectives of teaching, the learner, the structure of knowledge, and the knowledge-making process. During these training workshops, the theoretical foundation of the project could be discussed, leading to the major concepts and principles of teaching and learning. Although the project staff did not run any of these workshops during the two years of the project, other research, just now beginning as a result of our work, will examine the influence of relatively short periods of training coupled with interpersonal recall sessions (Kagan, 1975; Way,1981) for the improvement of teaching and learning in the classroom. We anticipate that two half-day workshops preceding use of the strategies, perhaps before the school year begins, with follow-up seminars once or twice a month, should serve both to establish and maintain an *espirit de corps* and to share ideas needed for successful implementation of the strategies.

Consistency of "V" Map Scoring:

As with our procedures for concept map scoring, we have continued to evolve new scoring procedures for "V" maps, and we would encourage continued experimentation with scoring procedures. For the purpose of of summative evaluation, however, we have applied the criteria shown in Appendix I, page V-14, for all "V" maps reported here. To test for the consistency in "V" map scores from rater to rater, "V" maps for six different students, and for three different laboratory exercises were scored by six raters. The relevant experience and mean scores for each rater on all eighteen "V" maps are shown in Table VI.4.

The mean ratings for the eighteen different maps are relatively consistent, except for rater #3, a teacher who worked with our project for eighteen months. Some of the difference may accrue from the fact that "V" map ratings require somewhat more sophisticated understanding of the theory behind the "V" maps and comprehensive knowledge of the relevant science.

Table VI.5 shows data from an analysis of variance which indicates a significant difference in both raters' map scores and scores for each of the eighteen maps (F = 8.61 and 16.58, respectively). While considerably more variance occurred in scores for the eighteen "V" maps, the data also show significant variation among the raters' scores. A Duncan's Multiple Range test was conducted as shown in Table VI.6. These data show that raters #1, 5, and 6 are consistent, and raters #1, 2, 4, and 6 are consistent. Only rater #3 (the classroom teacher) stands apart from the others. Taken together, the data suggest that consistency in "V" map scoring is more dependent on knowledge of the relevant theory on which the knowledge "V" is based than are concept map scores. All scores for "V" maps were done by project staff members (mostly by raters #1 and 5) and hence we can reasonably conclude that there is consistency in these ratings.

Table VI.4. Mean total scores from eighteen laboratory exercises using "V" mapping for six raters with varying experiences with the "Learning How to Learn" Project.

Rater and Experience	Means of Total Score (18 "V" maps)
#1 - worked in project eighteen months; helped devise criteria	11.833
#2 - graduate student at Cornell; not involved with project, but familiar with strategies	11.500
#3 - project teacher; worked with project for eighteen months	9.333
#4 - graduate student at Cornell; not involved with project; but familiar with strategies	11.389
#5 - involved with project for one year as staff member	12.667
#6 - graduate student consultant; not at Cornell; familiar with project ideas	11.833

Table VI.5. Two way analysis of variance (ANOVA), depending on rater and "V" maps.

Source	df	Sum of Squares	Mean Square	F	P
Model	22	850.0370	38.6380	14.77	.001
Error	85	222.3703	2.6161		
Corrected Total	107	1072.4074			
Rater	5	112.6296		8.61	.001
"V" Maps	17	737.4074		16.58	.001

Table VI.6. Duncan's Multiple Range Test for Variable Totals. Means with the same letter are not significantly different.

Groupings	Mean	N	Rater #
A	12.67	18	5
A B	11.83	18	1
A B	11.83	18	6
B	11.50	18	2
B	11.38	18	4
C	9.33	18	3

VII. TRANSFER OF LEARNING AND CONCEPTUAL QUESTIONS

One of the most difficult evaluation problems educators have faced over the past half century of formal test development has been how to assess gains in knowledge that can be evidenced in enhanced ability to solve problems or to transfer learning to new areas of application. A pioneer in this work, Ralph W. Tyler (1930, 1934), devised some ingenious tests to measure abilities to apply and use knowledge, but this evaluation problem persists today. More recent efforts such as Bloom's (1956) "Taxonomy," Novak's (1961) "problem solving test" and Nedelsky (1965) and Hodges (1966) suggestions must be considered. Nevertheless, these evaluation works have not led to evaluation instruments that are at once valid, reliable and practical. Many educators have resorted to modified Piagetian clinical interview as the only valid alternative to this evaluation problem (see Pines, et al., 1978). Although we have also employed the clinical interview strategy for evaluation purposes, we sought to develop alternative evaluation approaches for assessment of meaningful learning that could bear on the issue of whether or not the "learning to learn" strategies in this program were effective. This, in some ways, has been our greatest challenge.

We have already presented arguments to indicate that "concept mapping" and "V mapping" can be effective strategies for assessment of meaningful learning. However, educators cannot use these evaluation strategies unless students are first instructed to understand and construct concept maps and "V" maps. While the most significant outcomes of our recent theoretical work may be the development of strategies for teaching concept mapping and "V" mapping, and thus simultaneously to provide better pedagogical tools for assessment of educational achievements, these strategies cannot be employed with "uninstructed" students. We have found ourselves in a kind of "Catch-22" where the best evaluation strategies to demonstrate the potential effectiveness of our "learning to learn" strategies cannot be used. Consequently, we have had to resort to other, more conventional strategies for assessment of meaningful learning as indicated through students' ability to use knowledge acquired in novel problem-solving settings. What follows are descriptions of some of our efforts toward this objective.

Pendulum/Elodea Interviews:

Our efforts began in late 1978 and early 1979, as the staff began to devise a two part clinical interview involving a pendulum and Elodea plants. The intention of the interview was to determine whether the students could use the strategies of concept mapping to organize their own concepts about the events of the interview and the knowledge "V" to apply those concepts through the events to reach a knowledge claim.

After showing a demonstration of a pendulum and the period of its motion, the students were asked to identify those variables that might affect the period of the pendulum. (See the interview protocol on page VII-3.) After the students had identified a number of variables (mass of weight, height above the table, or the length of the string), the interviewee was encouraged to test each one to see if each individual variable did indeed affect the period. These were tested in turn and knowledge claims were constructed from the inquiry.

In the Elodea example, the interviewee was presented with a demonstration involving the presence of light and the generation of bubbles (of oxygen) as the light was absorbed by the Elodea plants. (See interview protocol on page VII-4.)

PENDULUM PROBLEM - Materials Needed for Interviews

2 weights of unequal mass with hooks on them
a piece of string with at least two loops in it
a stand from which to suspend the string and pendulum weight
a piece of paper and pencil

1. INTRODUCTORY SEQUENCE:

1. What we have here is a stand, a string with loops on it and two weights with hooks that do into the loops like this (demonstrate).

2. Do you know what this thing is called when you put a weight hitched to something so it can swing freely? (introduce "pendulum")

3. Have you ever seen one of these before?
Where?
Anywhere else?

4. Have you ever seen a grandfather clock or a cuckoo clock with a pendulum on it?

5. Why do you think they would use a pendulum on a clock?

6. How do you think it works to keep time?
(It keeps time by the number of times it goes back and forth every minute. On a carefully built pendulum, it will swing back and forth a long time before it changes the number of times it goes past some mark in one minute.)

7. When people first made clocks with pendulums, they had a lot of trouble making them run on time. Some ran too fast, some ran too slow. How do you think they fixed this problem of getting the pendulum to run at the right speed?

(Outline the variables and write them down)
Probe: What do you think would have to be changed?

II. EXPERIMENT DESCRIPTION:

1. What we want to know is what you'd have to do to change the number of times this pendulum goes past the center post in a certain time period. You've mentioned ______ and _________.

2. Do you think that any of these things would make the pendulum move past the center post at a different number of times per minute?

3. How could we find out which are the most important. How could we test it? What would you need to do to figure out how to change the number of times it goes past the center post? Which of those factors you mentioned.

4. How would you check to see the number of times it goes by the center post?

5. How would we see if those things really did affect the number of times the pendulum goes by the center post?

III. CONDUCT OF EXPERIMENT:

1. What do you think will happen if you change the _______________?

2. Why don't you try it?

3. Now what would you do? Try it.

4. Is that what you thought would happen?

5. What other things would you test?

6. Is that what you expected?

7. What would happen if you put the other on? Try it.
8. Is that what you expected?

IV. CONCLUSIONS

1. So, now that you've done this experiment, what do you think affects the number of times the pendulum goes past the center post?

2. If you look at the differences, what could you say? What could you conclude?

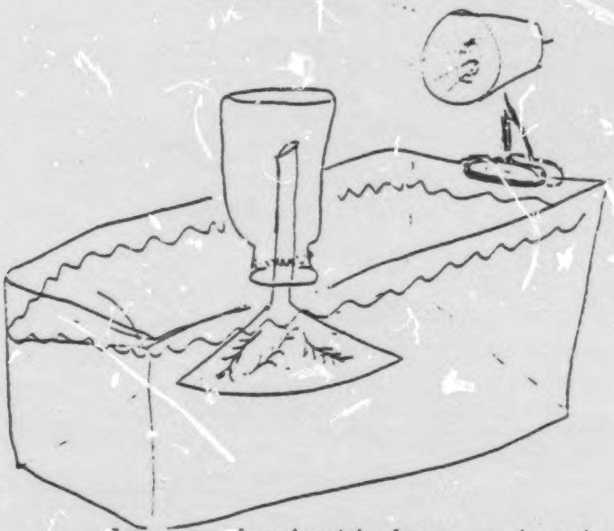
3. What did we look at? Did length matter?
Did the weight matter? How about the force, the distance?

4. If you were that scientist of 500 years ago now, how would you fix a clock that was running too fast?

Figure VII.1a. Pendulum problem protocol for clinical interview. This and Elodea example were the early attempts to evaluate the concept mapping and "V" mapping strategies and their effect on meaningful learning. Boynton Junior High School and Lansing Middle School, December, 1978 - March, 1979.

ELODEA PROBLEM - Materials Needed

2 containers, at least 5 inches deep and large enough to put a funnel in
3 funnells with long narrow neckd (powder funnels will not do)
three test tubes or clear poly-bottles to fit over the funnel neck (for collecting the gas that the plants will evolve)
a lamp to attach to the large containers
Elodea plants - buy fresh if possible. Do not use same plants for more than two days. One bunch is plenty for two or maybe three interviewers.
BAKING SODA
water
extra light bulbs



General set-up of the Elodea experiment.

1. Cut off the base of the Elodea plant at an angle so lots of surface area is exposed.
2. Fill the poly-bottle with water from the already filled large container.
3. Place the plants in the large container, under a funnel, and slip the poly-bottle over the neck of the funnel. Set the funnel upright, keeping the mouth of the poly-bottle submerged.
4. Be sure that the cut end of the plants are pointing upward into the neck of the funnel, but not blocking exit of any bubbles which will be formed.
5. Attach light.

Set up two funnels with plants, one in each of the large containers. Illuminate one of these, keep the other in the dark or in only room light. Set up a control (funnel without plants) in the container in the light. Add a tablespoon or so of baking soda to the plants in the light, (to stimulate bubble evolution.) ALLOW FIFTEEN MINUTES FOR THIS THING TO WARM UP AFTER YOU SET IT UP.

If all else fails, let more air into the setup with plants in the light than the one in the dark. Don't let any air into the control.

ELODEA QUESTIONS:

1. Here's an experiment that some scientists are doing, and this is how they set up the materials. Co8uld you tell me what the differences are between these? First, I'll tell you what's not important (health of plants, age of plants, extra bubbles on the side, temp of water, height of water in big container). Could you describe these three setups?

2. What do you think the scientists are trying to study with a setup like this? What do you think the setup is trying to prove?

3. Why do you say that?

4. Do you see anything else? How about the space in the bottles?

5. Where do you think that comes from?

6. Is there anything happening that you can see?
Probe: Do you see the bubbles going up the funnel? Do you think that has anything to do with the air in the bottle?

7. So what do you think is going on here?
What do you think the scientists are trying to get smart about?

8. Do you have any ideas just from your everyday experience that might help explain this experiment?

9. What kinds of observations will they make? What will they notice?

10. Do the scientists need to have any special ideas to understand what is happeni

11. What do you think the scientists would be able to conclude at the end of the experiment?
Probe: If you look at the differences, what could you say?
Reapeat question #8.

Figure VII.1b. Elodea problem protocol for clinical interview. This and the pendulum example were the early attempts to evaluate concept mapping and "V" mapping strategies and their effect on meaningful learning. Boynton Junior High School and Lansing Middle School December, 1978 - March, 1979.

Two set-ups were presented: one in a darkened room or room light, the other exposed to more intense light. After a few moments the set up with the greater light exposure began to generate bubbles. The interviewee was then asked to account for this observation. Approximately twenty-five clinical interviews, using these two protocols, were conducted in Lansing and Boynton (Ithaca) during the four month period of December, 1978 through March, 1979.

Several problems with this approach became apparent either immediately or as the staff began to focus in upon the objective of this phase of the evaluation. First, the interviews were too lengthy. While the pendulum example was shorter (15-20 minutes), the Elodea example ran in some cases to forty minutes. This, of course, would discourage widescale implementation of this evaluation strategy since it required too much time to evaluate a large sample of students.

The second reason for the inadequacy of the protocols derived from the number of concepts needed by the student for the interview inquiry. In the pendulum example, the interviewees were required to understand only a few concepts and principles in order to make sense of the event. In fact, most "everyday" understanding of concepts such as "time," "mass," "length," or "swing" were sufficient. In contrast, the Elodea example required a vast store of concepts and principles involving "photosynthesis," "carbon dioxide generation," "light intensity," and the like to sort out that inquiry. So in one interview we found a paucity of concepts, while in the other, too many. This reflects in part the difference in assessment of "spontaneous" versus "non-spontaneous" concepts (Vygotsky, 1962).

The experience with the pendulum and Elodea interviews led us to reevaluate again the project objectives regarding assessment of transfer of learning. It was clear that problem solving tasks unrelated to classroom instruction, or only remotely related, were too often tests of general reasoning ability (use of "if...then" propositions) or willingness to perservere with an obscure task. Once again we were brought back to our basic theoretical premise that problem solving ability is largely dependent on the adequacy of relevant concepts that the student has, and we were failing to provide appropriate problem solving tasks for this fact.

Problem Solving Related to Class Work:

Lansing Middle School was working with the laboratory-oriented Introductory Physical Science Program (IPS). Therefore, the staff decided to employ a problem solving situation involving phases of matter, and boiling and melting points. Further, it was decided that the protocol should be a pencil and paper test so that a large sample could be evaluated with a corresponding reduction in the amount of time necessary to perform the evaluation. See Figure VII.2 for a copy of this task.

While the approach eliminated the difficulties inherent in the clinical interview protocols used earlier, our first effort in this class-content-related problem was less than satisfactory. First, the approach required too few concepts to answer the questions. Upon inspection of the questions, it should be evident that only the concepts of "solid," "liquid," "gas," and "phase change" would be required to answer the majority of the questions. In other words, we had failed to delve deeply enough into the relationships among the concepts to prod the student into revealing their understanding

A scientist conducted experiments to learn about some of the characteristics of pure substance. This substance was a solid at room temperature, but would form a liquid when heated. During one experiment, the scientist heated the substance and then allowed it to cool. He observed the substance every thirty seconds and also recorded its temperature. Here are his results:

30 seconds - 80°C - Substance is a liquid.
1 minute - 70°C - Substance is a liquid.
1½ minutes - 60°C - Substance is a liquid.
2 minutes - 55°C - Substance is a liquid.
2½ minutes - 54°C - Substance started to form a solid.
3 minutes - 54°C - More of the substance is forming a solid.
3½ minutes - 54°C - Most of the substance has formed a solid.
4 minutes - 52°C - Substance is all solid.
4½ minutes - 45°C - Substance is a solid.
5 minutes - 35°C - Substance is a solid.
5½ minutes - 25°C - Substance is a solid.
6 minutes - 22°C - Substance is a solid.
6½ minutes - 22°C - Substance is a solid.
7 minutes - 22°C - Substance is a solid.

Answer the following questions:

1. Do you think that this scientist used any theory to help guide him in setting up his experiment? Explain your answer. No because it looks like an easy experiment and almost anyone could do it.

2. Describe some method which could help organize his data so that it could be more easily used. Put it all on a chart so it is easier to follow.

3. Do you think that the thermometer was broken? Explain. No because the temperature didn't go up that high and it probably just stick in the solid

4. Why do you think the temperature stayed at 54°C for 1½ minutes? Because it was in its phase change

5. Why do you think the temperature stayed at 22°C for 1½ minutes? Because it showed that the object was finally solid.

6. What is the freezing temperature for this substance? How do you know? 22°c and less. Because it shaved it as a solid and anything less would be also a solid.

7. What is the melting temperature of this substance? How do you know? 55°c. Because it was no longer a solid.

8. Why was energy given off at different rates during this experiment? Because it was changing its form.

9. How might the observations have been different if the substance was cooled in an ice water bath? Because it would not be melting it would be on its way back to a solid or freezing point

10. Can you describe an experiment that could help you determine the melting point of chocolate? Melt the chocolate and when it was fully melted it would be at its melting point

Figure VII.2. Problem solving task based on the Introductory Physical Science (IPS) Program. This task was tried in Lansing Middle School, March-April, 1979.

of the conceptual structure surrounding the event. Second, which is a corollary to the first objection, since the task required too few concepts, it was reduced to a logic problem, involving mostly "if...then" kinds of answers. These shortcomings were clearly evident from the records we collected. A similar problem format was tried with seventh grade students at Trumansburg. This problem dealt with a paragraph describing mosses and liverworts, followed by a series of multiple choice questions. Upon further analysis of responses and test items, it was concluded that there were serious objections to the validity of this problem as designed. The 1978-1979 school year ended with much work remaining to be done in our efforts to assess transfer of learning.

With several new staff members joining the project in August, 1979, we resumed our efforts to evaluate transfer of learning with general discussion of the purposes and goals, and a review of previous problems and progress. Out of these discussions emerged a guiding protocol that was subsequently employed to develop our "evolution problem." The protocol for this example is shown on page VII-9.

The Evolution Problem:

It was decided early that perhaps the best way for students to demonstrate their understanding of the conceptual structure of the discipline was to have them write an essay-type answer, rather than depending on their ability to identify the conceptual relationships among several relationships given in a multiple choice questions. The "evolution problem" was constructed and administered to seventh grade biology students at Trumansburg. Scoring was done by checking students' answers to identify concept relationships shown in the concept map (Figure VII.3) and any other relevant statements.

PROTOCOL FOR CREATING QUESTIONS REQUIRING TRANSFER OF LEARNING

1. Select a subject area to which the students have already been exposed to in class.

2. Construct a concept map of this subject area (see below).

3. If necessary, split up and rewrite the concept map so that they are never wider than two concepts at any point in the hierarchy.

4. Design a series (or set) of questions that address the concepts on the map in a fashion that leads from the bottom to the top of the hierarchy.

5. The questions should be structured so that each successive question relates to the ones that precede it.

6. The student should be able to answer each question in a few short sentences.

7. The actual questions should incorporate material that the student has been exposed to, but should be different enough so that only meaningful learning can be employed to answer the question.

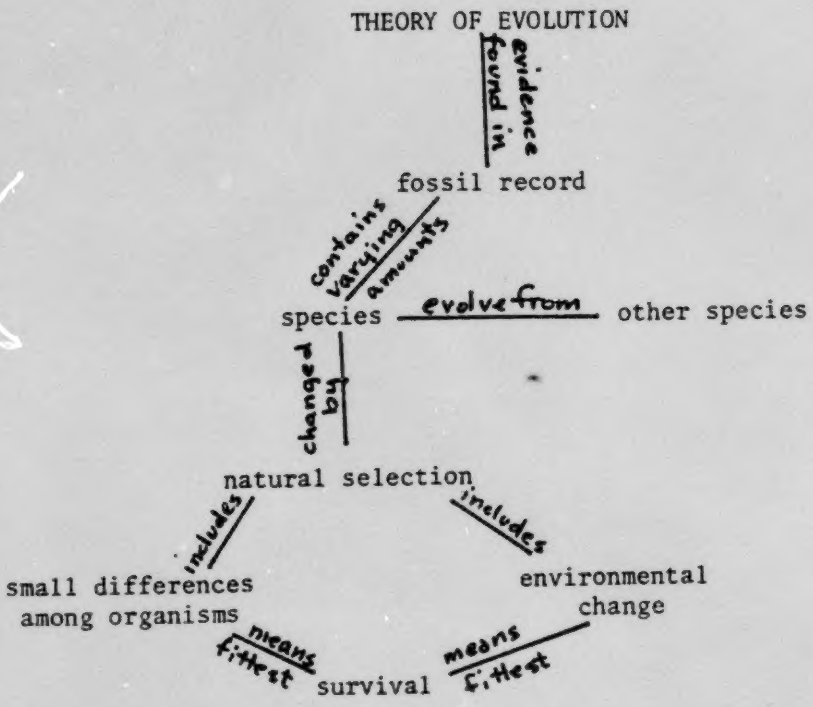
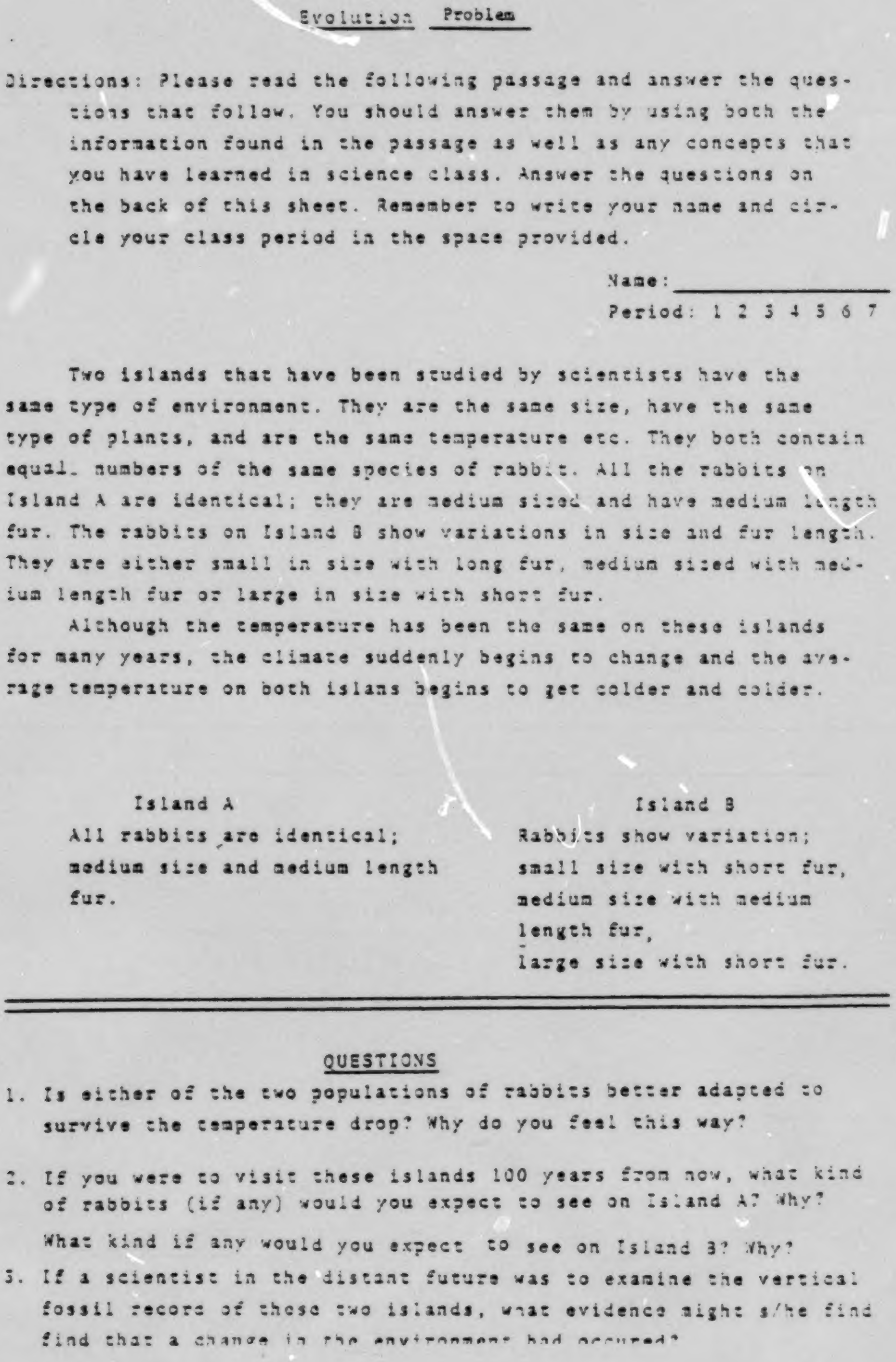

THEORY OF EVOLUTION
evidence found in
fossil record
contains varying amounts
species
evolve from
other species
changed by
natural selection
includes
includes
small differences among organisms
environmental change
means fittest
means fittest
survival

Figure VII.3. Concept Map used to develop "Evolution" conceptual question.



Evolution Problem

Directions: Please read the following passage and answer the questions that follow. You should answer them by using both the information found in the passage as well as any concepts that you have learned in science class. Answer the questions on the back of this sheet. Remember to write your name and circle your class period in the space provided.

Name: ____________________

Period: 1 2 3 4 5 6 7

Two islands that have been studied by scientists have the same type of environment. They are the same size, have the same type of plants, and are the same temperature etc. They both contain equal numbers of the same species of rabbit. All the rabbits on Island A are identical; they are medium sized and have medium length fur. The rabbits on Island B show variations in size and fur length. They are either small in size with long fur, medium sized with medium length fur or large in size with short fur.

Although the temperature has been the same on these islands for many years, the climate suddenly begins to change and the average temperature on both islans begins to get colder and colder.

Island A	Island B
All rabbits are identical; medium size and medium length fur.	Rabbits show variation; small size with short fur, medium size with medium length fur, large size with short fur.

QUESTIONS

1. Is either of the two populations of rabbits better adapted to survive the temperature drop? Why do you feel this way?

2. If you were to visit these islands 100 years from now, what kind of rabbits (if any) would you expect to see on Island A? Why?

   What kind if any would you expect to see on Island B? Why?

3. If a scientist in the distant future was to examine the vertical fossil record of these two islands, what evidence might s/he find find that a change in the environment had occured?

Figure VII.4. The "Evolution" conceptual question given to students in Trumansburg, Fall, 1979.

While the "evolution problem" did require students to use the concepts of evolution presented in class to answer the questions posed, some shortcomings were found. First, the items were too difficult for most of the students to answer. It required the student to draw upon a large group of concepts that were related, but not explicitly discussed in class. Also, there was not enough structure to the questions to focus the students' attention to the problem, i.e., trying to reach a claim about an event using the conceptualizations of the theory of natural selection. (See Figure VII.4 for the actual question.) Some insights did emerge from this attempt. First, the task did concentrate on and required the use of concepts to explain an event. Second, the event was a true inquiry event, even if it was a contrived example. A scientist could theoretically come upon such a pair of islands, and could make projections as to which population would survive better given certain environmental changes. Third, it required the students to write and express their understanding of the relationships among the concepts. This attempt helped to define the general format for the construction of these kinds of questions during the last six months of the year. Although the format did indeed change as new examples were tried, all these changes came as a result of necessary reconceptualizations about the evaluation task.

The Acetabularia Example:

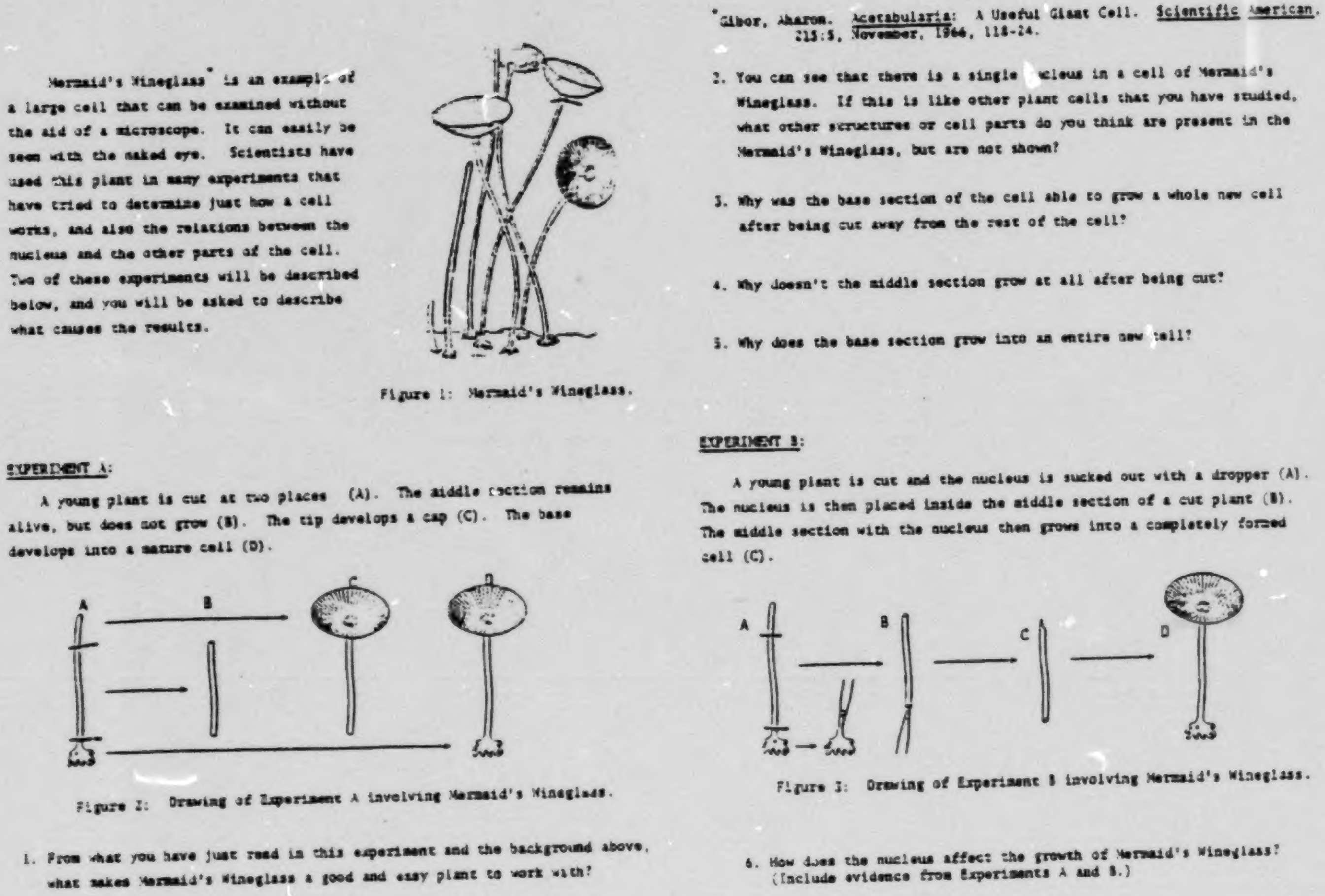
Encouraged by the findings about the construction of this kind of "conceptual question" (the label used after November, 1979), the staff began to develop another example based on a piece of primary research. Reported in SCIENTIFIC AMERICAN, the example dealt with Acetabularia (Mermaid's Wineglass), a large one-celled algae that is especially conducive to cytology studies.

A description of the organism and the questions administered to the students is illustrated in Figure VII.5.

A report of basic research was selected for the question to again provide the students with a true example of inquiry. Obviously, though, the reporting of the research was necessarily "scaled down" to accommodate the junior high science student. Concept maps were prepared from the article (see page VII-14), and the subject matter of the cell and the cell theory were presented to the students in their classes. The function of the two concept maps was to guide in the construction of the questions which were then devised for each of the experiments reported in the original SCIENTIFIC AMERICAN article.

In our first attempt with this instrument, we worked with small groups of students (N = 6) in Trumansburg to "walk them through" the example. From this initial experience, we determined that the task was too difficult in its original form, since students were unable to relate what they knew about the structure of the cell to this example. Also Acetabularia was too exotic to the students; they had only worked with the more common classroom examples of cells: onion, Elodea, and cheek cells.

From our experience with this question, the staff decided to pursue a problem more conceptually relatable to what the student could ordinarily be expected to encounter in the course of conventional classwork. This was the impetus to the development of the "winebottle example."



Mermaid's Wineglass* is an example of a large cell that can be examined without the aid of a microscope. It can easily be seen with the naked eye. Scientists have used this plant in many experiments that have tried to determine just how a cell works, and also the relations between the nucleus and the other parts of the cell. Two of these experiments will be described below, and you will be asked to describe what causes the results.

Figure 1: Mermaid's Wineglass.

EXPERIMENT A:

A young plant is cut at two places (A). The middle section remains alive, but does not grow (B). The tip develops a cap (C). The base develops into a mature cell (D).

Figure 2: Drawing of Experiment A involving Mermaid's Wineglass.

1. From what you have just read in this experiment and the background above, what makes Mermaid's Wineglass a good and easy plant to work with?

*Gibor, Aharon. Acetabularia: A Useful Giant Cell. Scientific American. 215:5, November, 1966, 118-24.

2. You can see that there is a single nucleus in a cell of Mermaid's Wineglass. If this is like other plant cells that you have studied, what other structures or cell parts do you think are present in the Mermaid's Wineglass, but are not shown?

3. Why was the base section of the cell able to grow a whole new cell after being cut away from the rest of the cell?

4. Why doesn't the middle section grow at all after being cut?

5. Why does the base section grow into an entire new cell?

EXPERIMENT B:

A young plant is cut and the nucleus is sucked out with a dropper (A). The nucleus is then placed inside the middle section of a cut plant (B). The middle section with the nucleus then grows into a completely formed cell (C).

Figure 3: Drawing of Experiment B involving Mermaid's Wineglass.

6. How does the nucleus affect the growth of Mermaid's Wineglass? (Include evidence from Experiments A and B.)

Figure VII.5. The "Acetabularia Example" of the conceptual questions. This was the first time the staff attempted to use primary pieces of research adapted for junior high level. Trumansburg, November, 1979.

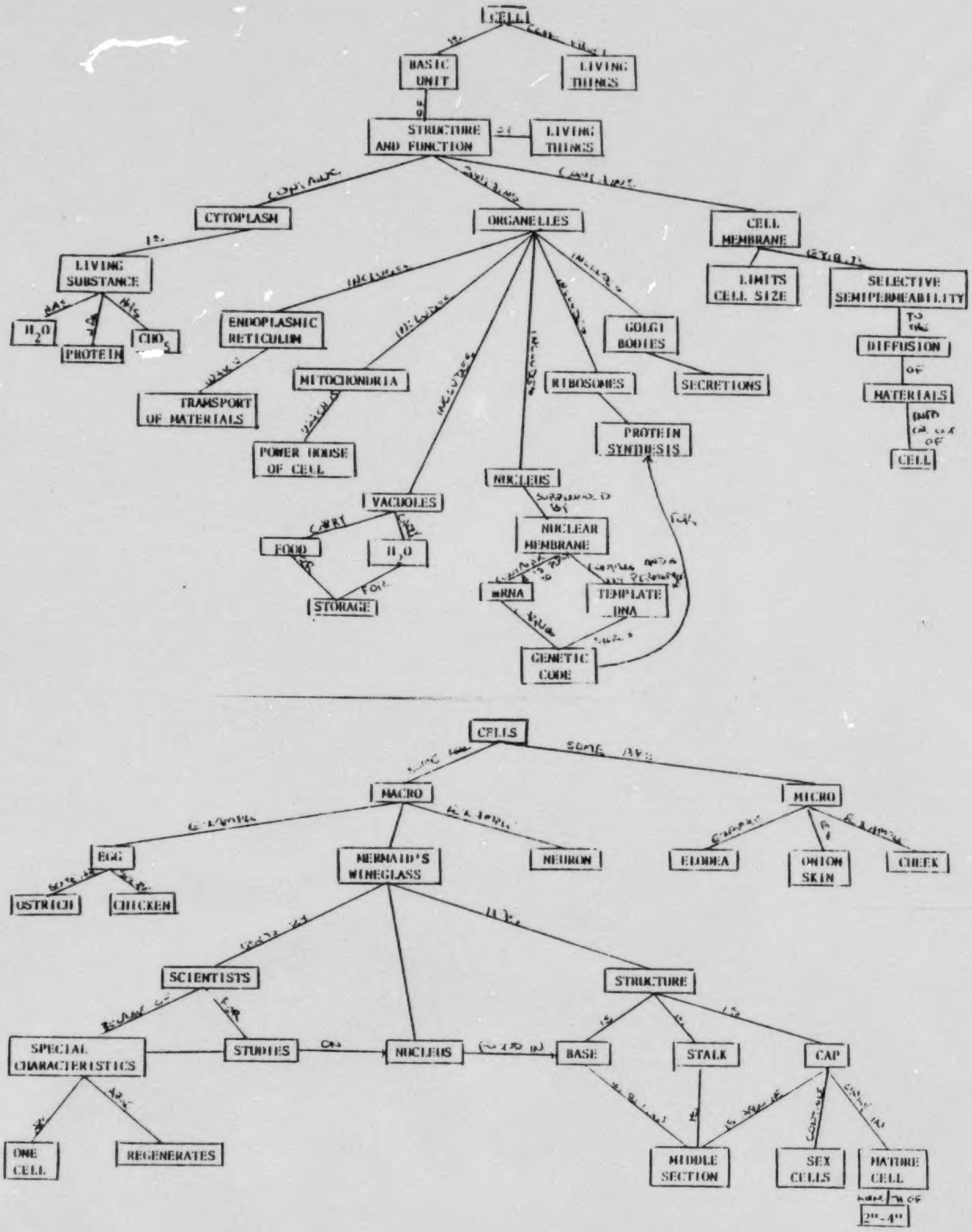

CELL
IS
BASIC UNIT
LIVING THINGS
STRUCTURE AND FUNCTION
OF
LIVING THINGS
CONTAINS
CONTAINS
CONTAINS
CYTOPLASM
ORGANELLES
CELL MEMBRANE
IS
LIVING SUBSTANCE
HAS
HAS
H_2O
PROTEIN
CHO_5
INCLUDES
INCLUDES
INCLUDES
INCLUDES
ENDOPLASMIC RETICULUM
MITOCHONDRIA
GOLGI BODIES
RIBOSOMES
SECRETIONS
TRANSPORT OF MATERIALS
POWER HOUSE OF CELL
PROTEIN SYNTHESIS
NUCLEUS
SURROUNDED BY
NUCLEAR MEMBRANE
mRNA
TEMPLATE DNA
GENETIC CODE
FOR
VACUOLES
CARRY
FOOD
H_2O
FOR
STORAGE
LIMITS CELL SIZE
SELECTIVE SEMIPERMEABILITY
TO THE
DIFFUSION
OF
MATERIALS
INTO
OF
CELL
CELLS
SOME ARE
MACRO
MICRO
EXAMPLE
EXAMPLE
EGG
OSTRICH
CHICKEN
MERMAID'S WINEGLASS
NEURON
ELODEA
ONION SKIN
CHEEK
SCIENTISTS
STRUCTURE
SPECIAL CHARACTERISTICS
STUDIES
ON
NUCLEUS
BASE
STALK
CAP
IS
IS
IS
ONE CELL
REGENERATES
MIDDLE SECTION
SEX CELLS
MATURE CELL
2"-4"

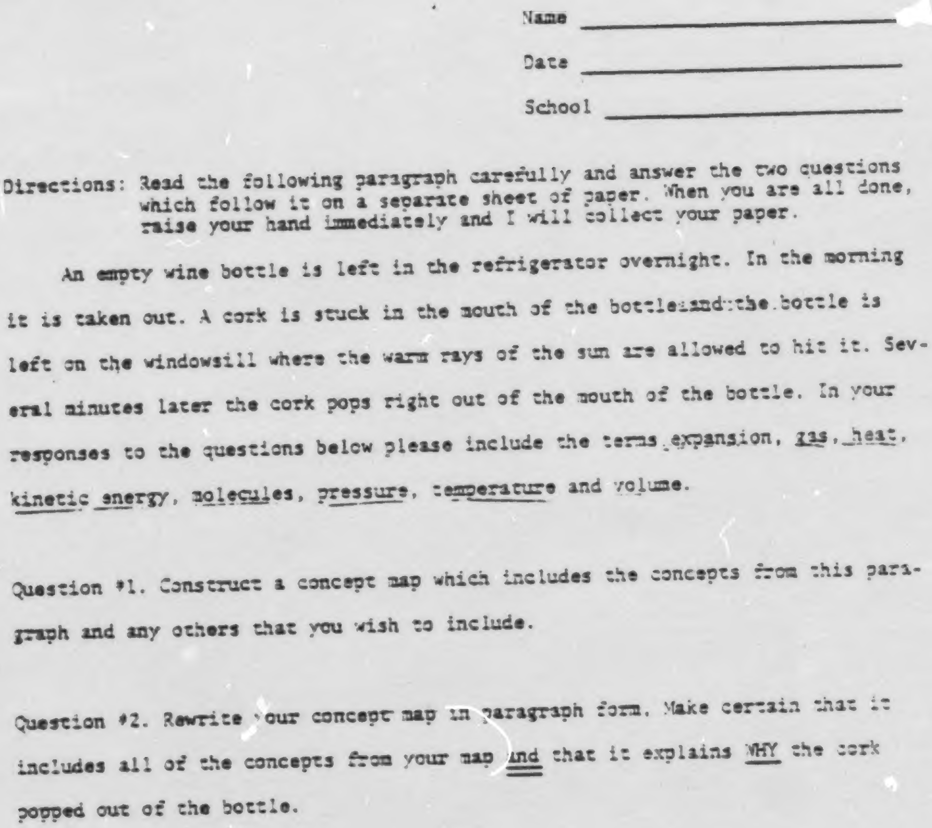
Figure VII.6. Concept maps used to prepare the "*Acetabularia* Example" of conceptual questions. Upper map represents concepts known about cell structure and function. Lower map prepared from concepts discussed in primary research article.

The Winebottle Example:

The "winebottle example" described below was essentially the culmination of several months of theoretical discussion on the content and context of a conceptual question. From the valuable experiences of previous attempts, the staff devised this example. One departure, however, from the previous attempts was included in this example. In addition to the posing of an inquiry event and a description of some record, we also included the concepts that we wished the students to use in the explanation of the event. This was done to prescribe limits and define the parameters that would form the bases of the students' answers. The important idea to keep in mind here is that to identify the concepts that could be used to sort out the event, these concepts must necessarily be learned meaningfully or the students would not be able to use those concepts in their answers. In other words, if the students were unable to relate the concepts to the event or to each other, it would become very evident in the explanations offered in the answers.

Upon examination of the "winebottle example" on page VII-16, the elements described above should be clear. First, an event is identified: the bottle has been moved from the refrigerator to the windowsill where the warm rays of the Sun shine upon it. Second, a record of the key event is also indicated: the cork pops off the bottle. Third, the major concepts necessary for the explanation are included in a non-conceptual manner, (in this case) alphabetically.

To facilitate the discussion of the construction and use of this example, a diagrammatical illustration of the winebottle example is provided on page VII-17. This is accompanied with an actual answer by one of the students in our study.



Name ______________________

Date ______________________

School ______________________

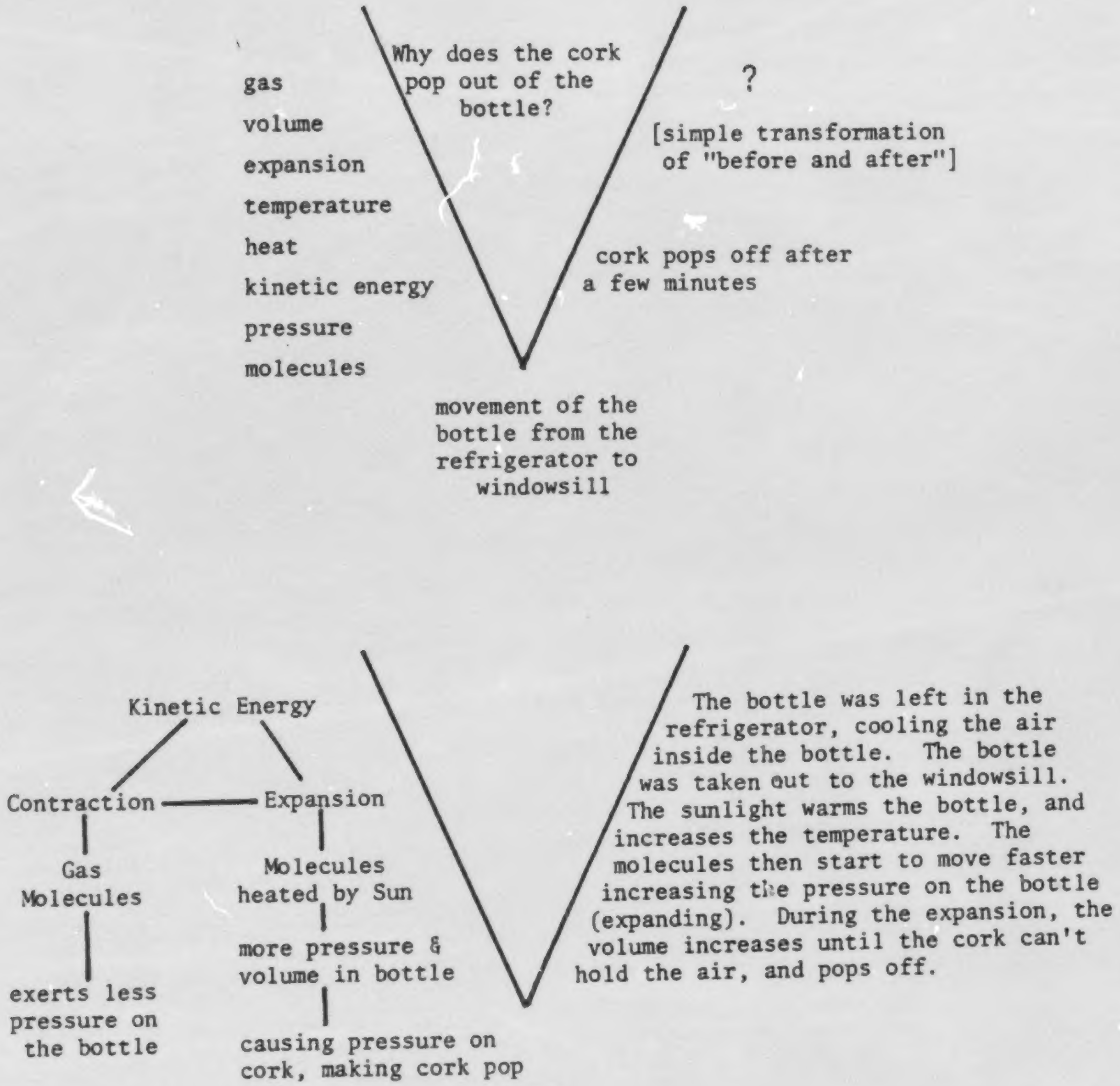
Directions: Read the following paragraph carefully and answer the two questions which follow it on a separate sheet of paper. When you are all done, raise your hand immediately and I will collect your paper.

An empty wine bottle is left in the refrigerator overnight. In the morning it is taken out. A cork is stuck in the mouth of the bottle and the bottle is left on the windowsill where the warm rays of the sun are allowed to hit it. Several minutes later the cork pops right out of the mouth of the bottle. In your responses to the questions below please include the terms expansion, gas, heat, kinetic energy, molecules, pressure, temperature and volume.

Question #1. Construct a concept map which includes the concepts from this paragraph and any others that you wish to include.

Question #2. Rewrite your concept map in paragraph form. Make certain that it includes all of the concepts from your map and that it explains WHY the cork popped out of the bottle.

Figure VII.7. "Winebottle Example" of the conceptual questions. This is the first time concepts that we wanted the students to use were included in the evaluation task. Vestal, Spring, 1980.


Why does the cork pop out of the bottle?
?
gas
volume
expansion
temperature
heat
kinetic energy
pressure
molecules
[simple transformation of "before and after"]
cork pops off after a few minutes
movement of the bottle from the refrigerator to windowsill
Kinetic Energy
Contraction
Expansion
Gas Molecules
exerts less pressure on the bottle
Molecules heated by Sun
more pressure & volume in bottle
causing pressure on cork, making cork pop

The bottle was left in the refrigerator, cooling the air inside the bottle. The bottle was taken out to the windowsill. The sunlight warms the bottle, and increases the temperature. The molecules then start to move faster increasing the pressure on the bottle (expanding). During the expansion, the volume increases until the cork can't hold the air, and pops off.

Figure VII. 8 . Diagrammatic representation of question, event, and concepts given students in the winebottle example (above); actual student's (#160) concept map and answer to the question posed in the winebottle example of a conceptual question.

Data from the Winebottle Example:

The "Winebottle" examples was administered to both instructed and uninstructed groups of eighth grade students at the African Road Junior High School in Vestal in March, 1980. Students wrote out their answers on pieces of paper, and then these were marked according to the number of correct relationships among concepts that the students wrote. Also evaluated were the number of misconceptions that these same students wrote in their answers. Results from the two groups are reported below in Tables VII.1 and 2.

Table VII.1. Frequency distribution for the number of correct conceptual relationships identified by both instructed and uninstructed students in the "winebottle" example.

	Number of Correct Relationships									
	0	1	2	3	4	5	6	7	Mean	S.D.
Instructed (N = 46)	6	8	10	11	5	2	3	1	2.60	1.40
Uninstructed (N = 42)	16	5	11	7	2	1	0	0	1.45	1.72

Table VII.2. Frequency distribution for the number of misconceptions identified by both instructed and uninstructed students in the "winebottle" example.

	Number of Misconceptions									
	0	1	2	3	4	5	6	7	Mean	S.D.
Instructed (N = 46)	27	16	3	0	0	0	0	0	0.41	0.62
Uninstructed (N = 42)	25	12	5	0	0	0	0	0	0.52	0.71

The number of students writing correct relationships and misconceptions in relation to the total number of students from each group are represented in Figures VII.9 and 10, respectively,

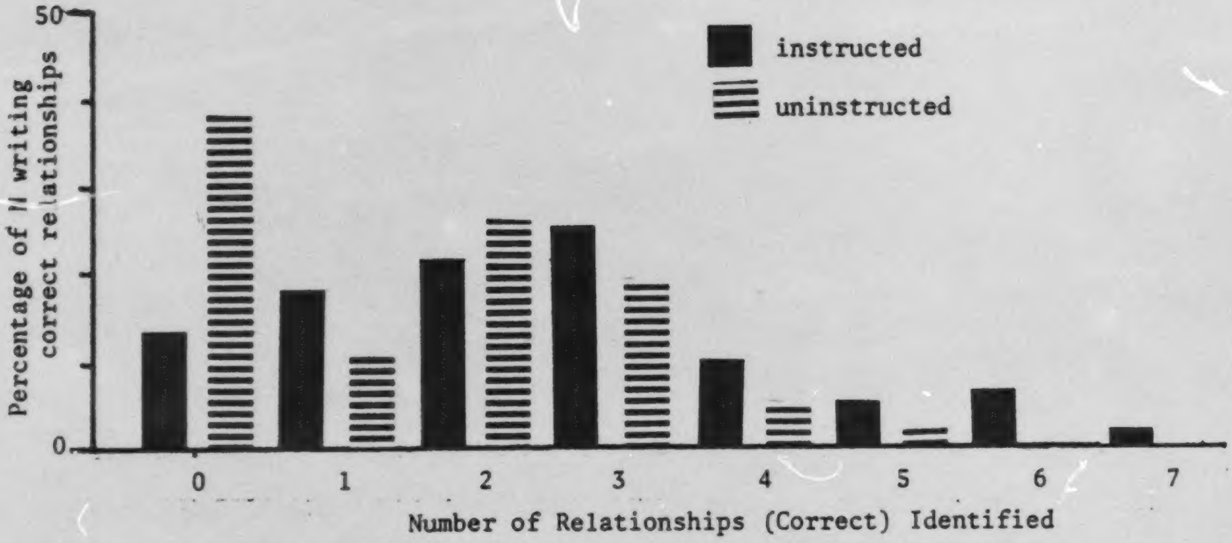


Figure VII.9. Comparison of number of relationships identified to number of students in the sample for both instructed and uninstructed.

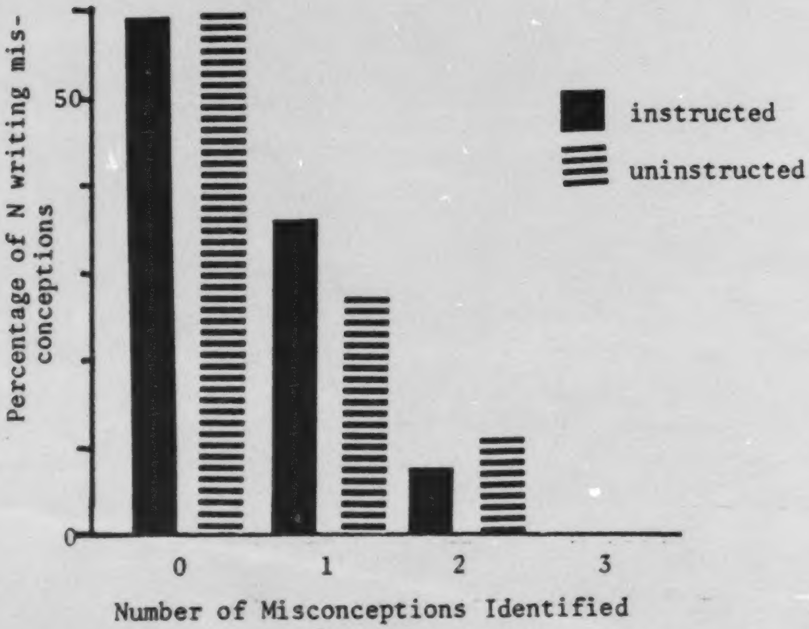
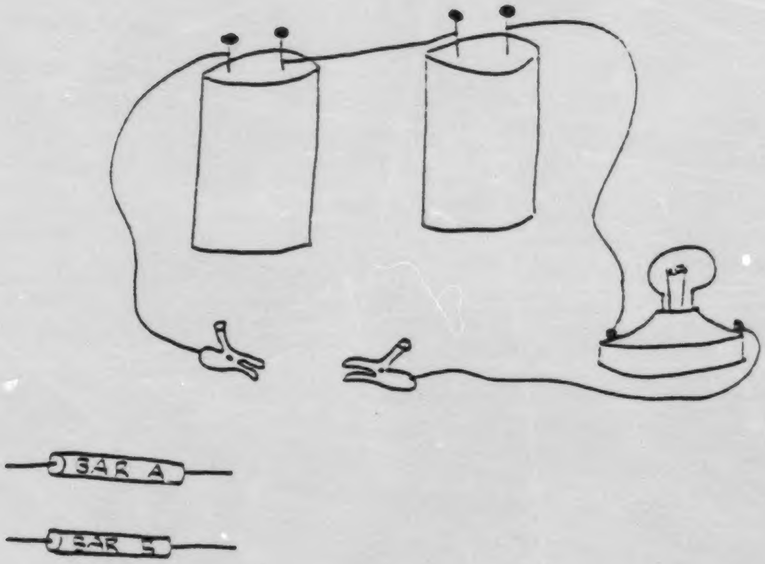


Figure VII.10. Comparion of number of misconceptions identified to number of students in the sample for both instructed and uninstructed.

The Electricity Example:

With growing confidence that our "winebottle" example had laid the foundation for the evaluation of student use of the strategies of concept mapping and the knowledge "V" for meaningful learning, our next attempt tried to enhance our understanding by providing variation in the type of evaluation strategy used. In this problem we sought not only to determine if students could relate a theoretical structure to an inquiry event, but a theoretical structure that the student had not previously used in classroom for similar events. The event of the question dealt with electrical conductance: two bars, each in turn, are used to complete a circuit. One bar produces a brighter light than the other. Rather than have the students explain that event in terms of "conduction," "resistance," and "current" alone, they were asked to explain the event in terms of atomic theory. (See Figure VII.11 for "electricity example," including event and concepts provided to the students.)

Another departure from the "winebottle" example dealt with the construction of concept maps by the instructed groups prior to the answering of the question. In keeping with the notion that concept mapping is only a heuristic device that functions to facilitate meaningful learning, one sample of students who had been exposed to the mapping strategy in class were not asked to construct a concept map before answering the question. One half of that same sample were asked to construct the concept map. Our null hypothesis, then, was that the construction of a concept map immediately prior to the evaluation task has no effect on the quality of the constructed explanation. Of course, the uninstructed group was not asked to make a concept map to answer the question.



The apparatus in Figure 1. was set up by a science teacher. Bar A and Bar B are exactly the same size but are composed of different materials. When Bar A is used to complete the circuit the bulb lights up very dimly but when Bar B is used to complete the circuit the bulb lights up brightly.

Question: What must be happening inside of Bar A that is different from what is happening inside of Bar B? Use as many of the following concepts as you can to answer this question or any other concepts that you wish to include: attraction, conductor, charge, electron, insulator, resistance, proton. (Construct a concept map before you begin writing to help you organize your thoughts.)

Figure VII.11. "Electricity example" of the conceptual questions. Like the "winebottle example," this task also provided students with concepts and major event.

7

One final departure of the "electricity" example from the "wine-bottle" example was the distinction among the kinds of correct relationships and misconceptions that students indicated in their answers. In this task, the students were asked to apply an atomic model to what would otherwise be called an electrical event. For that reason, two types of relationships were identified, atomic and electrical. Further, students employed logical principles ("if...then" statements) to support their arguments in the explanations. A category was established for this, then, also. Finally, hypothetical principles (such as, "Bar A could possibly contain more electrons than Bar B.") was also included as a category.

The attempt of these categorizations was to determine the actual source of students'conceptions and misconceptions about the nature of the phenonmena of interest, in this case, the differential lighting due to the presence of two different conductors. This, of course, can have important implications for planning and teaching, since by knowing the source of students' understanding about certain events, the teacher can adapt the instruction to reinforce correct relationships and rectify or reconcile misconceptions.

Data from the "electricity" example:

Tables VII.3 and 4 contain the data for the "electricity" example. The first table compares the instructed and uninstructed groups relative to their performance for each of the categories mentioned above. Included also in that table is the number of misconceptions that students wrote in their attempt to answer the question. Because no logical or hypothetical misconceptions were tallied from the responses of the students, these categories of misconceptions are missing. (The reason that our staff did not want to record these areas, but rather concentrate of the content-related atomic and electrical principles, was to discourage the reduction of this assessment to one involving the testing of logical operations.)

Table VII.4 contains the data for only the instructed group divided into those who made a concept map prior to the evaluation task, and those who did not. Appropriate t-tests for these two tables will be discussed in Section IX, showing that differences between means for instructed and uninstructed groups students were significantly different.

Table VII.3. Mean correct relationships and misconception and standard deviations (in parentheses) for instructed and uninstructed students for the "electricity" example.

	Mean Correct Relationships				Mean Misconceptions	
Group	Atomic	Electrical	Logical	Hypothetical	Atomic	Electrical
Instructed (N = 31)	1.02 (0.90)	2.05 (1.13)	0.05 (0.27)	0.16 (0.48)	0.33 (0.59)	0.29 (0.62)
Uninstructed (N = 42)	0.59 (0.58)	1.47 (1.10)	0.07 (0.26)	0.45 (0.80)	0.40 (0.59)	0.17 (0.43)

Table VII.4. Comparison of results of the "electricity" example for those instructed students who made concept maps prior to answering the question, and those who did not. Numbers in parentheses are the standard deviations for those means.

	Mean Correct Relationships				Mean Misconceptions	
Group	Atomic	Electrical	Logical	Hypothetical	Atomic	Electrical
Concept Map not written (N = 41)	0.95 (0.71)	2.17 (1.11)	0.10 (0.38)	0.28 (0.64)	0.43 (0.68)	0.35 (0.74)
Concept Map written (N = 40)	1.09 (1.06)	1.93 (1.17)	0.00 --	0.05 (0.22)	0.02 (0.49)	0.24 (0.49)

Table VII.5 represents the frequency distributions for all of the correct relationship categories. These are then transformed to percentages of the total N number and represented in Figure VII.12. Frequency distributions for the total misconceptions are represented in Table VII.6, with accompanying percentage in relation to N-number in Figure VII.13.

Table VII.5. Frequency distributions for combined categories of correct relationships for both instructed and uninstructed groups for "electricity" example.

Group	Number of Correct Relationships											
	0	1	2	3	4	5	6	7	8	9	Mean	S.D.
Instructed (N=81)	3	7	16	18	25	6	3	0	2	1	3.28	1.68
Uninstructed (N=42)	2	9	7	12	10	2	0	0	0	0	2.60	1.33

Table VII.6. Frequency distributions for combined categories of misconceptions for both instructed and uninstructed groups for "electricity" example.

Group	Number of Misconceptions							
	0	1	2	3	4	5	Mean	S.D.
Instructed (N=81)	46	23	9	2	1	0	0.63	0.87
Uninstructed (N=42)	25	11	5	1	0	0	0.57	0.80

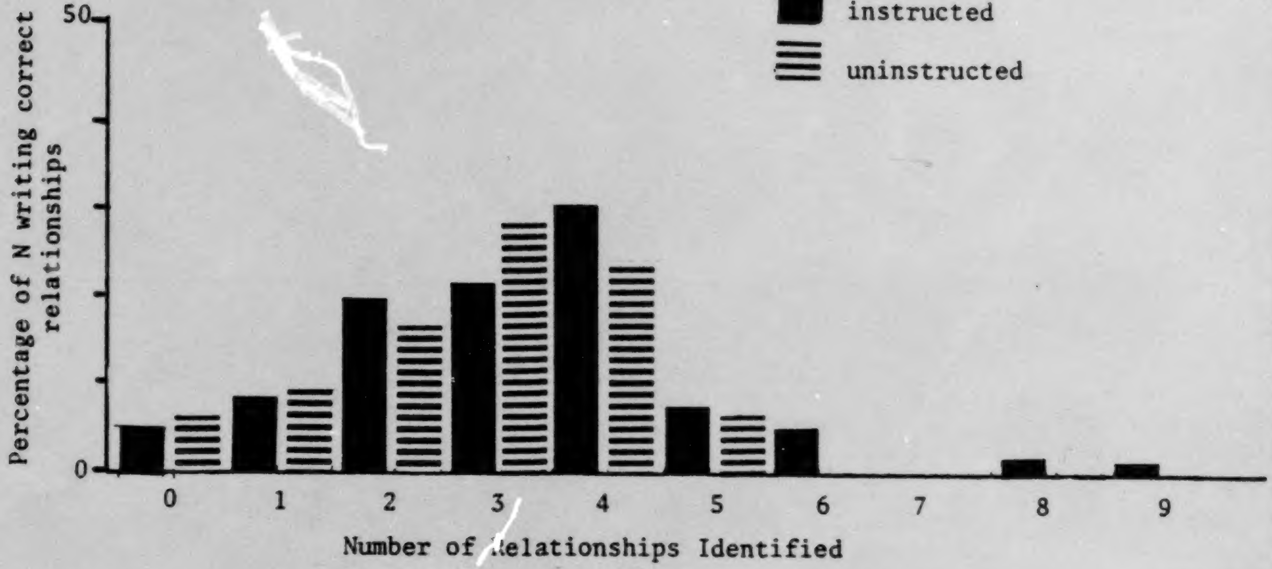


Figure VII.12 Comparison of number of relationships identified to number of students in the sample for both instructed and uninstructed.

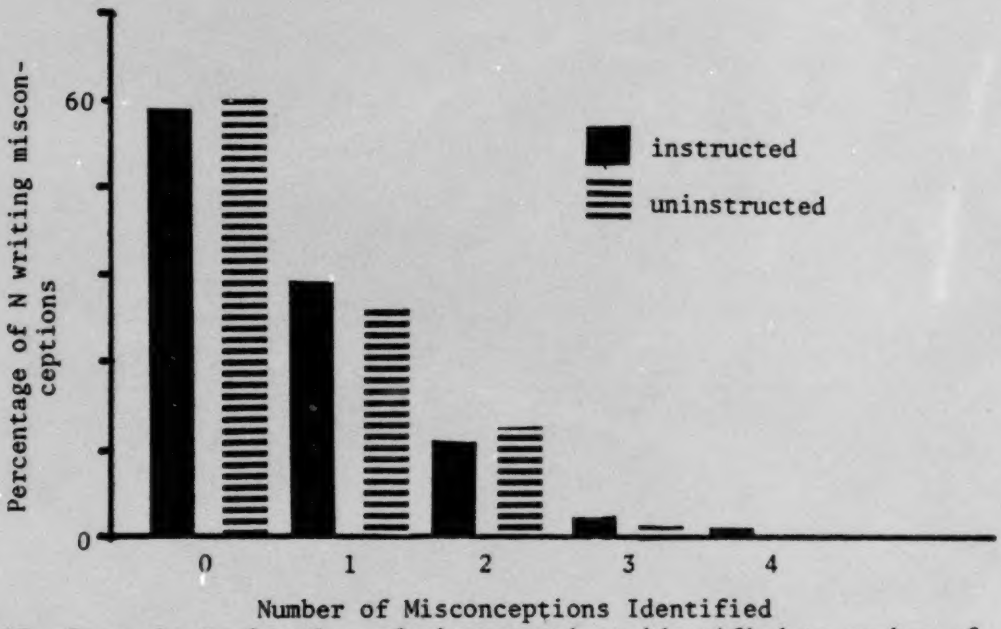


Figure VII.13. Comparison of number of misconceptions identified to number of students in the sample for both instructed and uninstructed.

VIII. ATTITUDE ASSESSMENT

Although the "Learning How to Learn" Project was primarily concerned with cognitive learning, the staff was also interested in determining if any changes in attitudes would accrue as a result of exposure to the strategies of concept mapping and the knowledge "V". We did not expect, nor did we observe, substantial changes in attitudes toward science for several reasons. First, the attitudes, as reflected on questionnaires by students, may indicate how they feel about their teachers or other factors related to school, rather than feelings related to use or non-use of the strategies. Second, the assessment instrument used, which is described in detail below, was limited in the number of items representing each of the four attitude areas surveyed. Third, the attitude effects of introduction of the "V" and concept mapping strategies perhaps may need much more time to develop in the students than the six to eight month duration of exposure to the strategies in this project. Furthermore, even in the "best case," only limited time on task (estimated to be 10-15%) may fall short of the time needed to effect significant changes in attitudes about science, learning, and knowledge.

This section reports on the attitude instrument's development, administration, and observed results.

Development of the Attitude Assessment Instrument:

The staff identified four general areas that might be affected by the introduction and use of these strategies in the classroom. It was felt that concept mapping might have some effect on how students felt about reading in science class. A section on attitudes about reading in science was included. The knowledge "V" was thought to affect how students perceived the laboratory experiences as a means of carrying on inquiry, so this subject also was addressed. The combination of these two strategies might provide a changed perspective on how knowledge is created in science, and a section on this issue was developed. Finally, all these areas should provide a general effect on students' attitudes about science class, and thus a fourth area of concern was identified.

With these four areas -- attitude about reading in science, attitude about laboratory work, attitude about the nature of knowledge, and general attitude about science class -- a preliminary forty-eight item questionnaire was devised in August, 1979, and was based on the work of Russell and Hollander (1975). Each item consisted of a pair of positive and negative statements. For instance, a positive item could state, "I like to read about science in the newspapers and magazines that we get at home," while its negative counterpart would read, "I don't read any more science than I have to."

For each of the four general areas identified above, positive and negative items were devised. A Likert-like scale of one through five accompanied each statement, with numerical values indicating a range of feelings from "strongly agreee" to "strongly disagree." During the marking of the questionnaires, positive statements would progress from one being "strongly disagree" through five being "strongly agree." If the statement was negative, the reversal was true. In both kinds of statements, a three indicated no preference either way, or "undecided."

This initial questionnaire contained forty-eight items with the following breakdown into the four general areas:

GENERAL ATTITUDE ABOUT SCIENCE CLASS = 14 items
ATTITUDE ABOUT READING SCIENCE = 12 items
ATTITUDE ABOUT LABORATORY WORK = 14 items
ATTITUDE ABOUT THE NATURE OF KNOWLEDGE= 8 items

After some initial editing by the project staff, an editing that concentrated on the reduction of ambiguity in the wording of the statments, the preliminary questionnaire was administered to the entire eighth grade class (N = 102) at one of the schools with which we were working. The eighth grade was selected for this sample because it was representative of the type of student with whom we were working in the project, but was not directly part of the project: the participating teacher at that school was the seventh grade teacher. However, twenty-three of these eighth graders were involved with our project materials during the previous school year (1978-1979), and in the analysis that followed this preliminary assessment, these 28 students' scores were deleted and the remaining responses analyzed (N = 79).

The averages for each area were computed. Total scores for the entire assessment were also calculated. Based on Russell and Hollander's recommendations, the upper 25% and the lower 25% of these preliminary assessments were used for the correlation analysis; the middle 50% were deleted. Each item was analyzed to find the correlation between the average score for the statement and the total score within the general category. For example, the statement, "I usually do well on science tests when I have studied," was correlated to the total score for the category "general attitude about science class." While Russell and Hollander recommended that the final questionnaire should be composed of only those statements which correlated at a 0.80 level or above, we had to reduce that to a 0.60 or above.* Another factor which affected the selection of items for the final product was the pairing of positive and negative items. The final assessment that was to be administered was planned to include both the positive statements and their negative counterparts.

Copies of the preliminary assessment and the final assessment that resulted from the former's analysis appear on the following pages. Included also, but which did not appear on students' copies, are the classifications according to the general categories identified (G = general attitude about science; R = attitude about reading; L = attitude about laboratory work; and N = attitude about the nature of knowledge). Whether these statements were considered positive or negative (represent as + or -, respectively), and the correlation value determined from the item analysis are also indicated after each statement. Items circled on the preliminary assessment were the ones chosen to be included in the final attitude instrument.

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*Setting a criterion of very high correlation leads to items that measure identical traits and reduces potential for identification of differences among individuals.

SCHOOL: ____________ DATE: ____________ CLASS: ____________

Instructions: This is a questionnaire to determine your feelings about science class, readings in science, and science in general. There are no correct answers to the statements. They only try to determine how you feel about certain topics. You are to indicate your feelings by circling the response that most closely matches your feelings.

Key: SA = strongly agree
A = agree
U = undecided
D = disagree
SD = strongly disagree

Sample Items:

A. I like hamburgers. [✓ SA] A U D SD

B. Television is good for people. SA A U [✓ D] SD

* ① I don't read any more science than I have to. *R- .893*	1.	SA	A	U	D	SD
2. I like to discuss a lab in class before we do it. *L+ .420*	2.	SA	A	U	D	SD
3. Planting seeds and watching them grow is a scientific experiment. *N- .380*	3.	SA	A	U	D	SD
④ I feel comfortable in science class. *G+ .769*	4.	SA	A	U	D	SD
⑤ I like to read about science in the newspaper or magazines that we get at home. *R+.827*	5.	SA	A	U	D	SD
⑥ You have to be very smart to understand the work in science class. *G- .716*	6.	SA	A	U	D	SD
⑦ Lab exercises have nothing to do with the other work we do in science class. *L- .641*	7.	SA	A	U	D	SD
8. The methods of science are fine for the scientists, but there is little in these methods to help people with everyday problems. *L- . 513*	8.	SA	A	U	D	SD
9. I usually do well on science test when I have studied. *G+ .650*	9.	SA	A	U	D	SD
⑩ Science class makes me feel very uneasy. *G- .802*	10.	SA	A	U	D	SD
⑪ Theories never try to explain more than what is already known. *N- .739*	11.	SA	A	U	D	SD

---

*Circled items represent items selected for the final instrument. R- indicates attitude toward reading science;L- indicates attitude toward laboratory work. N- indicates attitude toward the nature of science and G- indicates general attitude toward science. Plus and minus signs indicate if the scale was regarded as positive or negative for agreement. Numbers indicate correlation values.

12. It is hard to do the laboratory exercises in science classes. L- .601 — 12. SA A U D SD

13. Scientists use theories because they are useful to explain natural events. N+ .283 — 13. SA A U D SD

14. I don't think anything would help me understand what happens during laboratory exercises. L- .542 — 14. SA A U D SD

15. I don't look forward to coming to science class as much as my other classes. G- .135 — 15. SA A U D SD

16. Theories are used in science because they are true. N- .780 — 16. SA A U D SD

17. I learn more about science from labs and activities that I do on my own. L+ .031 — 17. SA A U D SD

18. Laws in science are statements which never change. N- .486 — 18. SA A U D SD

19. Usually, I find the labs are easy to do. L+ .558 — 19. SA A U D SD

20. I like science because all my friends are in the same class. G- .254 — 20. SA A U D SD

21. I like to read about scientific topics. R+ .971 — 21. SA A U D SD

22. I have trouble remembering what conclusions or observations or hypotheses are when I do a lab in science class. L- .649 — 22. SA A U D SD

23. I would like science even if my friends were not in the same class. G+ .628 — 23. SA A U D SD

24. Generally, I think science could be understood by almost eveyone. G+ .681 — 24. SA A U D SD

25. I believe that the methods of science can be used to solve many everyday problems. L+ .616 — 25. SA A U D SD

26. I am usually more confused about a topic after I read a section in a science book. R- .545 — 26. SA A U D SD

27. Laboratory exercises help me understand the concepts in science class. L+ .614 — 27. SA A U D SD

28. Science class is boring. G- .821 — 28. SA A U D SD

29. Labs and activities I do on my own confuse me more than class discussions. L- .010 — 29. SA A U D SD

30. When I do a lab, I can tell which parts are the observations, conclusions, etc. L+ .467 — 30. SA A U D SD

31.	Reading is a waste of time. R- .765	31.	SA	A	U	D	SD
32.	I general, I have a good feeling about science class. G+ .848	32.	SA	A	U	D	SD
33.	I can always apply what we learn in the lab to the subject matter. L+ .557	33.	SA	A	U	D	SD
34.	It makes me nervous when I have to do the work by myself in a lab exercise or activity. L- .577	34.	SA	A	U	D	SD
35.	I find science class interesting. G+ .883	35.	SA	A	U	D	SD
36.	After reading something, it is important to ask yourself questions about what you have just read. R+ .397	36.	SA	A	U	D	SD
37.	I like working in lab exercises and activities better than class discussions. L+ .115	37.	SA	A	U	D	SD
38.	Just doing things in the laboratory doesn't make something scientific. N+ .649	38.	SA	A	U	D	SD
39.	Theories are used to explain existing facts and predict future events. N+ .009	39.	SA	A	U	D	SD
40.	Scientific laws can be modified as theories are changed. N+ .592	40.	SA	A	U	D	SD
41.	Science readings are always difficult to understand. R- .628	41.	SA	A	U	D	SD
42.	After I have read something in science, I feel comfortable that I understand what I have read. R+ .270	42.	SA	A	U	D	SD
43.	When I read, I don't like to try and find the major concepts. R- .444	43.	SA	A	U	D	SD
44.	I enjoy reading. R+ .680	44.	SA	A	U	D	SD
45.	I think it is important to pick out the major concept when I read science. R+ .769	45.	SA	A	U	D	SD
46.	Labs only confuse me more about what I am supposed to know in science class. L- .682	46.	SA	A	U	D	SD
47.	Science tests are too hard even when I do study for them. G- .721	47.	SA	A	U	D	SD
48.	To understand what you have read, all you have to do is read it; nothing else. R- .586	48.	SA	A	U	D	SD

ATTITUDE ASSESSMENT - NSF Project

SCHOOL: ____________ DATE: ____________ CLASS: ____________

Instructions: This is a questionnaire to determine your feelings about science class, readings in science, and science in general. There are no correct answers to the statements. They only try to determine how you feel about certain topics. You are to indicate your feelings by circling the response that most closely matches your feelings.

Key: SA = strongly agree
A = agree
U = undecided
D = disagree
SD = strongly disagree

Sample Items:

A. I like hamburgers [✓ SA] A U D SD

B. Television is good for people. SA A U [✓ D] SD

*1. I don't read any more science than I have to. R- .893	SA	A	U	D	SD
2. I feel comfortable in science class. G+ .869	SA	A	U	D	SD
3. I like to read about science in the newspapers or magazines that we get at home. R+ .827	SA	A	U	D	SD
4. You have to be very smart to understand the work in science class. G+ .716	SA	A	U	D	SD
5. Lab exercises have nothing to do with the other work we do in science class. L- .641	SA	A	U	D	SD
6. Science class makes me feel uneasy. G- .802	SA	A	U	D	SD
7. Theories never try to explain more than what is already known. N- .739	SA	A	U	D	SD
8. Reading is a waste of time. R- .764	SA	A	U	D	SD
9. In general, I have a good feeling about science class. G+ .848	SA	A	U	D	SD
10. I find science class interesting. G+ .883	SA	A	U	D	SD
11. Science readings are always difficult to understand. R- .628	SA	A	U	D	SD
12. I enjoy reading. R+ .680	SA	A	U	D	SD

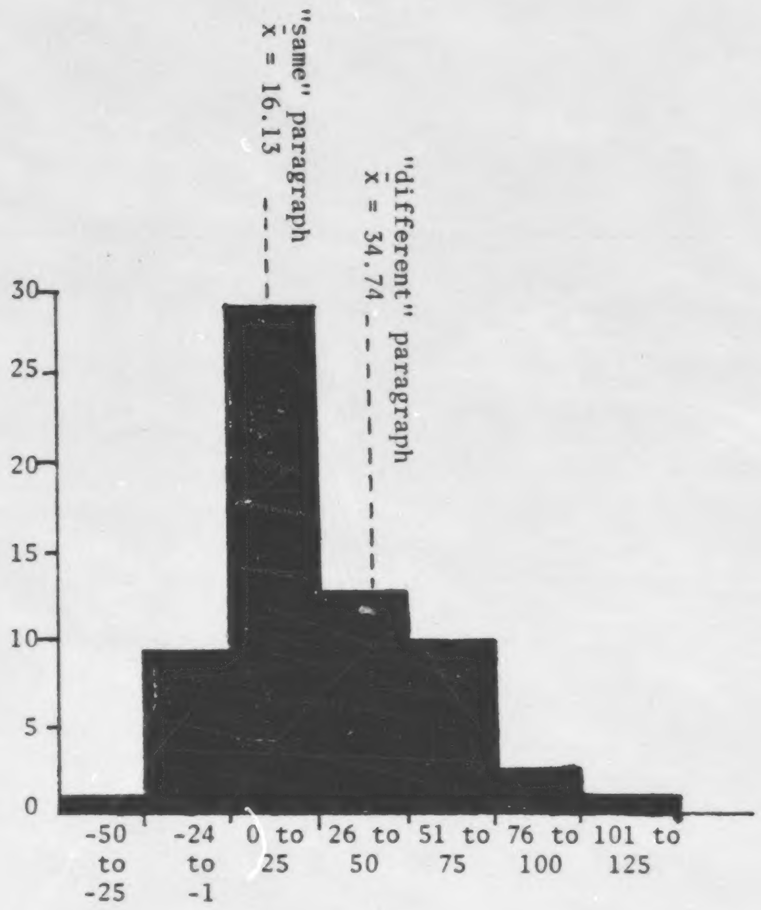

Figure IX.1. Frequency distribution for change in total score for students who made concept maps during two evaluation sessions. Means indicated for those students who had identical paragraphs as previously ("same") and those who were evaluated with different paragraphs ("different"). N = 66.

13. Labs only confuse me more about what I am supposed to know in science class. L- .682 SA A U D SD

14. Theories are used in science because they are true. N- .786 SA A U D SD

15. I like to read about scientific topics. R+ .971 SA A U D SD

16. Generally, I think science could be understood by almost everyone. G+ .681 SA A U D SD

17. Laboratory exercises help me understand the concepts in science class. G+ .614 SA A U D SD

18. Science class is boring. G- .821 SA A U D SD

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*See footnote on preliminary questionnaire.

Results of the Attitude Assessments:

The final form of the eighteen item attitude assessment was administered within the first ten days of the school year (1979-1980) in each of the classes with which we were working; four in Trumansburg, the five seventh grade classes in Vestal, and the four eighth grade classes in Vestal. Since we were trying to determine if there had been any change in attitudes relative to the areas that we defined, the first administration would provide a baseline for subsequent assessments during the school year. Three assessments (September, December, and March) were conducted in Trumansburg. Only two assessments (in September and March for the Vestal seventh grade, and September and April for the Vestal eighth grade) were administered in Vestal since they were delayed in using the strategies.

Questionnaires were completed anonymously, thus only class averages were computed. Since this instrument did not live up to the expectations of the project staff, only totals for each entire group, that is, all the students for each teacher, have been reported below. See Table VIII.1 on the next page.

Table VIII.1. Results of the Attitude Assessments given to the three groups of students. Numbers indicate average score for all students in that group. Numbers in parentheses are the N numbers for that sample. Fluctuations in the N numbers due more to daily changes in attendance, rather than movement in and out of the school districts.

	GENERAL ATTITUDE ABOUT SCIENCE			ATTITUDE ABOUT READING			ATTITUDE ABOUT LABORATORY WORK			ATTITUDE ABOUT THE NATURE OF SCIENCE		
	Sept.	Dec.	March	Sept.	Dec.	March	Sept.	Dec.	March	Sept.	Dec.	March
TRUMANSBURG-7th	3.61 (79)	3.79 (84)	3.92 (77)	3.35 (79)	3.56 (84)	3.63 (77)	3.86 (79)	4.16 (84)	4.25 (77)	3.16 (79)	3.08 (84)	3.10 (77)

	GENERAL ATTITUDE ABOUT SCIENCE		ATTITUDE ABOUT READING		ATTITUDE ABOUT LABORATORY WORK		ATTITUDE ABOUT THE NATURE OF SCIENCE	
	Sept.	March	Sept.	March	Sept.	March	Sept.	March
VESTAL-7th	3.77 (115)	4.60 (102)	3.35 (115)	3.29 (102)	3.96 (115)	4.12 (102)	3.38 (115)	3.27 (102)

	GENERAL ATTITUDE ABOUT SCIENCE		ATTITUDE ABOUT READING		ATTITUDE ABOUT LABORATORY WORK		ATTITUDE ABOUT THE NATURE OF SCIENCE	
	Sept.	April	Sept.	April	Sept.	April	Sept.	April
VESTAL-8th	3.60 (83)	3.48 (81)	3.31 (83)	3.31 (81)	4.11 (83)	4.25 (81)	3.47 (83)	3.38 (81)

Analysis of Results:

Although some of the classes and groups showed statistically significant positive changes in attitudes in most of the categories, no definite pattern or trend developed as a result of the introduction of these strategies. Several reasons that could affect the validity of this type of instrument should be discussed. While the students showed some gains in attitudes, that does not preclude the influence of other factors such as teacher personality, difficulty of the subject matter, or students' liking laboratory work (notice the generally higher scores for attitude about laboratory work in each of the groups).

It is encouraging, however, to see that all the groups are generally positive about their schooling (anything above a 3 suggests "agreement" with the statements and categories). But, again, other factors can influence that attitude level.

Formative Information on Attitudes:

During the course of clinical interviews and the more informal interviews with the students of the project, impressions and feelings were solicited regarding the value of concept mapping and the "V" strategies. In addition, their attitude assessment questionnaires provided space for students to react to the class, the project, or the questionnaire itself. Representative comments from the students from all these sources are reported below. If a question was asked, it is shown in caps. Though many of the questions and answers deal with cognitive elements, attitudes and feelings are also expressed in the students' remarks.

Sometimes the "V" makes it easier to understand the labs we do in class. At first, I didn't enjoy them, but I do now because they help me to understand the labs.

Generally, the "V's" help me understand what I'm doing better -- but at times they get me more confused. I get most confused on records and transformations.... Concepts are pretty easy most of the time, but sometimes they're extremely difficult [too].

IS THE "V" ANY GOOD?

Yeah, it gives you an answer to your question. It gives you a detailed answer to what you want to know in a ... simpler form.

HOW IS IT DIFFERENT, THOUGH, FROM A LAB WHERE YOU DON'T USE THE "V"?

Well, the lab where you don't use the "V" -- I don't know. I just have trouble remembering the basic thing in the investigation -- what the investigation is all about.

The staff collected many more comments about concept mapping than the "V" strategy. This is, of course, due to the fact that concept mapping was assessed in part with clinical interview on a one to one basis as indicated in the previous section on concept mapping (Section V of this report).

IS CONCEPT MAPPING ANY GOOD?

Yeah... if you save those [concept maps], it's alot easier to review instead of reading all those chapters over again. And it takes longer than just reading, but it's worth it if you want to review for a test or something.

HOW DO YOU FEEL ABOUT CONCEPT MAPPING?

At first, it was confusing. We didn't know what to do, but then it got easier and you could do it faster... [it got easier] after we did a couple of them.

ARE THEY [CONCEPT MAPS] ANY GOOD FOR YOU?

Yeah, they help me alot.

WHEN DO THEY HELP YOU OUT?

Well, most of the time, when I read, I can read fast, but it's fun when I go through it. It [concept mapping] gives me awhile to understand what's going on in my reading. But concept maps help you, so you know what you read, and you understand what you read.

We asked students to compare the strategy of concept mapping to conventional note-taking. Although reactions were mixed, we did find students thought concept mapping to be of value.

WHAT DO YOU THINK ABOUT PUTTING STUFF IN [CONCEPT] MAP FORM?

[It] helps me understand things better.

It helps me understand things more than a bunch of notes and stuff, all scrambled together.

YOU MEAN THE NOTES YOU TAKE IN CLASS?

Yeah, 'cause you can put them right in order and then just separate them from what you're doing.

If you study for a test, you got all the right notes. All you gotta read is a word, a word right there.

IF YOU HAD A CHOICE BETWEEN NOTE-TAKING AND CONCEPT MAPPING, WHICH WOULD YOU USE?

Note-taking.

YOU LIKE THAT BETTER?

Well, it's easier for me to do.

TO MAKE A CONCEPT MAP IS HARD?

Sometimes, yeah ... to figure our what things branch off from others.

COULD YOU USE OUTLINING [NOTE-TAKING] THE SAME WAY YOU USE CONCEPT MAPPING?

It would be easier to do the outline, but with a concept map it matches together better. It makes a little more sense.

WHAT DO YOU MEAN "IT MATCHES TOGETHER"?

Well, like you can tell of the different parts of the topic.

WHAT DO THE REST OF YOU THINK?

I think outlining is easier. You're not dealing with as much stuff. You're not, like, drawing lines, [putting] lines on this side and that side. You're just putting them down under certain categories like A, B, and C. Stuff like that.

IX. STATISTICS AND ANALYSIS

Although the preceding chapters provided the major overview of the introduction of the concept mapping and the "V" strategies in the classroom, and some preliminary analysis, this chapter will report a more comprehensive statistical analysis of all the data. To characterize the populations of students with whom the project worked, scores from standardized achievement tests for each group of students are reported. These will then be followed by an examination of the change of concept mapping scores over time. Further, concept mapping performances will be related to the standardized scores reported.

Since the "V" for laboratory exercises was only done with the seventh grade students in Trumansburg, there can be no comparison between that group of students and the instructed seventh grade students in Vestal. The scores for the laboratory exercises written on the "V" will be related to the standardized scores for Trumansburg. One comparative study between the Trumansburg group and the Vestal eighth grade group can be reported. Each of these was evaluated on their performance to identify, define, and pick out examples of parts of the "V".

The most comprehensive evaluation involved both instructed and uninstructed students and dealt with conceptual questions. Both the "winebottle" and "electricity" examples will be discussed in detail.

In addition to the evaluation strategies employed by the project staff, we also examined the mean scores on classwork and final examinations for the three groups.

The final aspect of the analysis reports correlations among thirteen variables.

Standardized Tests to Characterize the Student Populations:

The three groups of students with whom we worked during the 1979-1980 school year had been administered some sort of standardized test to assess progress in the school program and to offer diagnostic information regarding programs and placement during subsequent years. The Scholastic Aptitude Test (SAT) was administered to the students in Trumansburg at the middle of their sixth grade (January, 1979). Similarly, the SAT examination was administered to the (then) sixth grade of Vestal during the month of January, 1978. These were the eighth grade students of our study. A School and College Ability Test (SCAT) was administered to the Vestal seventh grade in January, 1979.

Since there exists a difference in time between administration of a standardized test and the participation in this project, some of the information given below must be read relative to the time the students were examined. The project had no control over what examinations were given, or when they were administered. We had to rely on only the information that the schools were kind enough to provide to us.

Table IX.1 on the next page reports the mean averages for the SAT and SCAT scores for the three samples of our study. Table IX.2 reports the analysis of these scores into quartiles for each sample.

Table IX.1. Standardized achievement test results for experimental groups expressed as national grade equivalents or raw scores and national percentiles.

TRUMANSBURG 7th Grade (N = 81) administered in January, 1979

	Mean	Standard Deviation
SAT Reading: Grade Equivalent	8.20	2.03
SAT Reading: Nat'l %tile	64.64	25.30
SAT Math: Grade Equivalent	7.91	1.84
SAT Math: Nat'l %tile	61.82	25.02

VESTAL 8th Grade (N = 77) administered in January, 1978

	Mean	Standard Deviation
SAT Reading: Grade Equivalent	9.06	1.69
SAT Reading: Nat'l %tile	78.00	19.96
SAT Math: Grade Equivalent	8.82	1.61
SAT Math: Nat'l %tile	78.00	20.51

VESTAL 7th Grade (N = 101) administered in March, 1979

	Mean	Standard Deviation
SCAT Verbal: Raw Score	444.59	13.66
SCAT Verbal: Nat'l %tile	66.49	24.95
SCAT Quantitative: Raw Score	459.23	18.15
SCAT Quantitative: Nat'l %tile	73.93	23.15

Table IX.2. Experimental groups standardized achievement test results by quartiles as ranked on national norms.

School & Test	Quartile	N	Mean Nat'l %tile
Trumansburg			
SAT Reading	1st	17	28.88
	2nd	23	52.43
	3rd	21	78.04
	4th	20	85.00
SAT Math	1st	18	28.55
	2nd	20	48.80
	3rd	23	71.48
	4th	20	93.65
Vestal-8th			
SAT Reading	1st	18	48.06
	2nd	21	75.67
	3rd	20	89.80
	4th	18	97.56
SAT Math	1st	18	48.33
	2nd	19	74.95
	3rd	21	89.71
	4th	19	97.89
Vestal-7th			
SCAT Verbal	1st	32	28.00
	2nd	30	57.50
	3rd	31	79.26
	4th	28	94.82
SCAT Quantitative	1st	29	37.74
	2nd	36	51.61
	3rd	26	87.15
	4th	30	97.67

Examination of these two preceding tables show that the samples of students in the project demonstrated higher mean scores than the national norms. This can be expected, since the two school districts of the study were either rural-suburban and comprise populations with average or above average socio-economic status. However, as the data are analyzed in the following pages, it will be shown that students who measure comparatively low on standardized tests can perform adequately on the concept mapping and "V" strategies.

Concept Mapping:

One of the corrollary questions to this project was whether students improved over time in their ability to construct concept maps. Several clinical interviews were conducted in Trumansburg (October-November, 1979). Clinical interviews were also conducted in Vestal with both seventh and eighth grade instructed students (January, 1980). The results of these interviews are reported in Section V. The data showed a general trend from early improvement toward a "leveling off" for the remainder of the interval.

Other assessments, conducted during April-May, 1980, did not use the clinical interview protocol, but rather assessed students during regular class time. For the purposes of comparison, thirty-two of the students who were part of the earlier clinical interviews received the same paragraph as previously, while thirty-four of those previously interviewed received different paragraphs. In all cases, the students received a paragraph to map that was related to course subject matter that had been discussed that year.

Figure IX.1 shows a frequency distribution for the change in concept mapping scores for those sixty-six students who were assessed at two different times during the year. Generally, 15% of the sample performed at a lower level than they had during the previous assessment. Although it is not shown specifically in the figure, 21% of the students (14/66) exhibited no change in their total score from the first assessment to the second. Sixty-four percent of the students did better on the second assessment than the first. Of interest, though, is the average scores for those students who had the same paragraph and those who did not. As indicated in the figure, the mean score gain for those students who had the same paragraph was 16.13, while it was double that (34.74) for those students who did not have the same paragraph, suggesting either that the second paragraph was easier to map or that students showed more motivation in this "new" paragraph.

From this data, it can be suggested that the majority of students improve in their ability to make concept maps over a four month period. Although we could not conduct further assessments, it seems reasonable to assume that students, after a time, will begin to "level off" in performance, as was the case in Trumansburg where students had more experience in concept mapping over a longer period of time. A factor that might have also affected these results was that the first assessment was in a clinical interviewing setting and the second in the classroom. Admittedly, students are nervous during the clinical interviews, no matter how comfortable the interviewer attempts to make them feel, and this could account for the lower scores on the first assessment.

Another question that may be important to the implementation of concept mapping is the performance for each quartile of students as measured on standardized achievement tests. Table IX.3 illustrates the results of the seventh grade Vestal students for percentage total of baseline map scores against the four quartiles for those students as measured on the SCAT. Figures IX.2 and 3 shown the general trend for students in the highest quartiles to show higher performance on the concept mapping task. Nonetheless, there are clear indications that students in all quartiles can acquire and perform adequately on this strategy. Thirty-one

Table IX.3. Frequency distribution for percentage total of baseline maps for concept mapping and performance on SCAT classified according to quartiles. Two cases received a grade greater than 100% since those two students constructed concept maps better than the baseline map.

Frequency Range of total of the % of baseline	SCAT - Verbal 1st (28.00)	2nd (57.50)	3rd (79.26)	4th (94.82)	SCAT - Quantitative 1st (34.74)	2nd (51.61)	3rd (87.15)	4th (97.67)
	(Mean for that quartile: Vestal - 7th)							
0 - 29	11	8	4	4	11	8	4	4
30 - 59	14	14	12	9	12	17	12	8
60 - 89	6	7	13	8	5	10	10	10
90 - 109	0	0	0	2	0	0	1	1

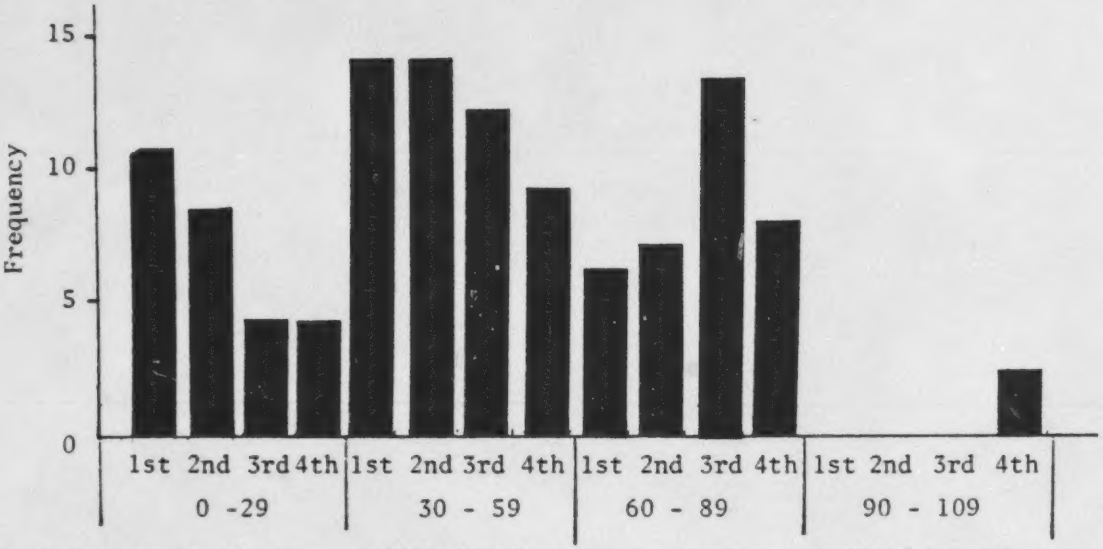

Table IX.2. Frequency distribution for percentage total of baseline maps for concept mapping and performance on SCAT-Verbal according to quartiles. Those cases where students scored higher than 100% indicate where they made a concept map better than the baseline map.

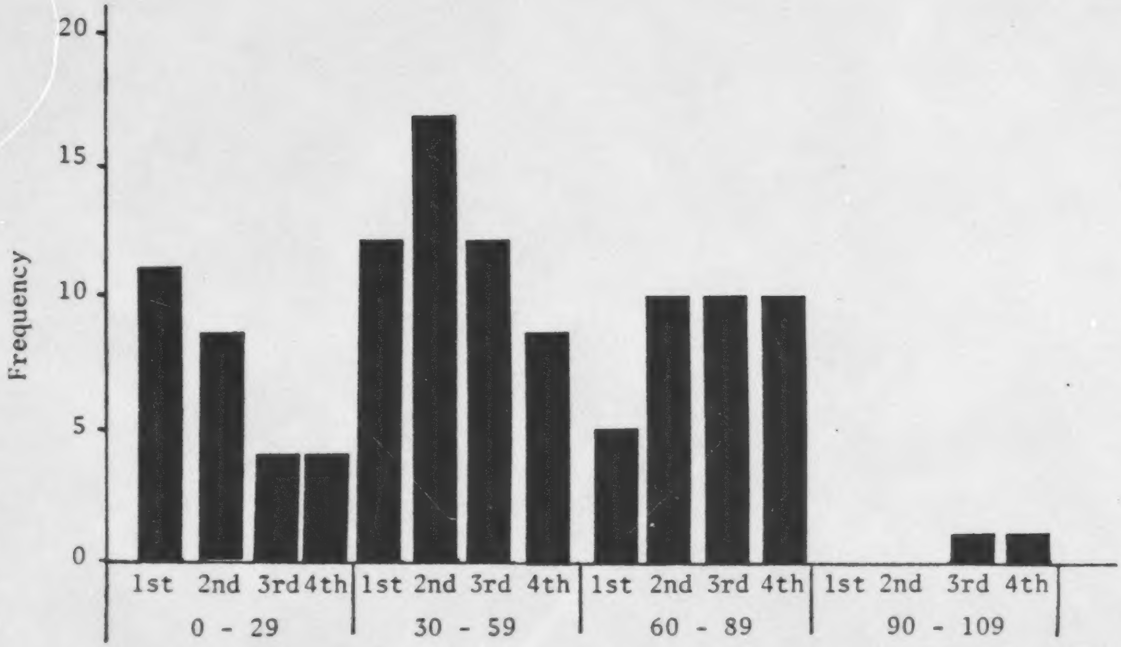

Table IX.3. Frequency distribution for percentage total of baseline maps for concept mapping and performance on SCAT-Quantitative according to quartiles. Those cases where students scored higher than 100% indicate where they made a concept map better than the baseline map.

percent of the students in the first quartile for SCAT-Verbal and 28% of SCAT-Quantitative first quartile have scores greater than 50% of the baseline score. Again, it is believed that if students have been given sufficient instruction in the criteria for making concept maps, the general scores for these percentages would have been greater, Further, if the amount of time on task had been increased from its low rate (5-15%) to a significantly higher percentage of time, students would have increased in their proficiency with a tendency toward mastery learning.

It should be noted that significant numbers of students in the top quartile on SAT tests were among the low scoring group on concept mapping performance. In part, this was due to their lack of effort and/or misunderstanding, but at least some of the lower performance could indicate a lack of ability to perform the type of evaluation tasks demanded in concept mapping. There is increasing evidence that students who perform high on standardized achievement tests or objective classroom tests do not necessarily understand the material they have studied. Concept mapping may prove to be a more valid indicator of meaningful learning than commonly used evaluation methods.

The Knowledge "V":

As mentioned earlier, the "V" strategy was introduced too late in the Vestal school to accumulate any records of students' performances on using the "V" for laboratory exercises. This, of course, caused a loss of an important aspect of comparison between the Trumansburg group who had been using the strategy since the beginning of the school year and the Vestal groups.

What can be assessed, however, from the Trumansburg students was how well they performed on laboratory exercises using the "V" over time in comparison to their standardized scores; this has already been reported in Section VI. Examination of those data indicates that students do appear to improve in their ability to use the strategy of the knowledge "V" over the course of a school year. The initial low scores in lab exercises #2 and #3 (exercise #1 had a small sample number, and will be disregarded in the analysis), might have been due to the relative difficulty of the exercises. But after several weeks, the students did begin to perform adequately on the subsequent exercises. It is realized that to compare these laboratory exercises together is inviting a criticism of invalidity since we must assume that all the exercises be considered of equal difficulty and comparable in terms of time spent on each exercise in class, as well as other factors.

There is another consideration that should be discussed concerning the scores of students using the "V". The "ideal" score for each laboratory exercise was eighteen, and most of the exercises written on the "V" clustered around the range of twelve to sixteen, indicating a percentage range from

68% to 88%. The reason for these comparatively low scores* may have been due to the lack of effort on the project staff and the teacher to make the criteria for assessing the "V's" explicit to the students. If the students had been made aware of the range of scoring for each criterion, and had been provided with clear cases of each marking, it is believed that the average score would have been higher. Another factor is that clear emphasis on theories and principles is generally lacking in junior high school science programs, resulting in a "ceiling" of about sixteen points. Thus, we might conclude that most students reached as high a level for the "V" strategy as could be expected, given the circumstances under which it was introduced and used.

For the purposes of comparing performances on using the "V" for laboratory exercises against standardized scores, Tables IX.4 and 5 are given below. Table IX.4 represents the quartile breakdown for all the laboratory exercises completed on the "V" (N=446) during 1979-1980. One-hundred and eleven laboratory exercises were completed by students classified in the first quartile for SAT Reading. Of those students, 44% scored in the high range (13-18), 44% scored in the middle range (7-12), and only 12% scored in the low range (0-6). For the SAT Math, the percentages are not that different. For the one-hundred and fifteen laboratory exercises completed on the "V" from students classified in the first quartile of SAT Math, 51% scored in the high range, 39% scored in the middle range, and only 10% scored in the low range. Table IX.5 illustrates the mean for all students who completed laboratory exercises

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*Teachers often use scores around 90% to indicate mastery. Considering the limitations of the science curriculum, however, an 80% mastery criterion might be high.

Table IX.4. Frequency distributions for scores of laboratory exercises completed in Trumansburg (N = 446) against quartile scores for SAT. Numbers in parentheses indicate mean percentiles on national norms for each quartile.

	SAT - Reading				SAT - Math			
Scoring Range	1st (28.88)	2nd (52.43)	3rd (78.04)	4th (85.00)	1st (28.55)	2nd (48.80)	3rd (71.48)	4th (93.65)
13 - 18	49	90	82	97	59	64	90	105
7 - 12	49	59	58	45	45	61	66	39
0 - 6	13	3	0	1	11	4	1	1

Table IX.5. Frequency distributions for means for all students who completed laboratory exercises (N = 61) against quartile scores for SAT. Numbers in parentheses indicate mean percentiles on national norms for each quartile.

	SAT - Reading				SAT - Math			
Scoring Range	1st (28.88)	2nd (52.43)	3rd (78.04)	4th (85.00)	1st (28.55)	2nd (48.80)	3rd (71.48)	4th (93.65)
13 - 18	1	6	9	13	2	3	9	15
7 - 12	15	7	6	4	14	8	8	2
0 - 6	0	0	0	0	0	0	0	0

using the "V". While 76% of the students classified in the fourth quartile for SAT Reading averaged in the high range, 94% of those students classified in the first quartile for SAT Reading were able to achieve an average within the middle range. No students, from any of the four quartile for each of the parts of the SAT, averaged within the low (0-6) range.

The data from both these tables support the conclusion that students in all ability quartiles, as measured by SAT tests, can perform satisfactorily (7-12) or well (13-18) on "V" mapping. When we take into account that a few students in the Trumansburg classes were doing next to nothing in any of their science work (our strategies notwithstanding), the data are indeed encouraging. This claim receives additional validity from the fact that some students in the top quartile perform poorly, suggesting that the usual measures of ability do not necessarily indicate facility in "V" mapping.

One opportunity did present itself to seek a comparison between two instructed groups relative to the use of the "V". Both Trumansburg and the eighth grade Vestal group were assessed to determine if the students could identify, define, and give examples of terms of the "V". Preliminary data, from both these groups, are reported in Section VI.

As mentioned earlier, Trumansburg was assessed twice, once in October and again in April (week 26). Because of the very different nature between the first and second Trumansburg assessments, the results of the second administration are only reported. Further, the question of whether the the first assessment had any effect on the performance of the second assessment seems at least very minimal since the two instruments were very different in structure and content. Vestal had the revised instrument administered in May (week 33).

The instrument was composed of three questions. Question #1 asked the student to place each of the nine terms of the "V" in their proper positions. Question #2 asked the student to define, in their own words, each of the nine terms. Question #3 asked the student to pick out examples of each of the terms given in a laboratory exercise that was completed in class during the school year. Since the Vestal eighth grade and Trumansburg seventh grade were covering different material, we necessarily administered different completed laboratory exercises for this third question. (The entire instrument with the two laboratory exercises are illustrated on pages V-10 and V-11 in Appendix I.) Both groups of students, then, had identical Questions #1 and #2, but a different Questions #3.

Tables IX.6 and IX.7 report the t-tests comparing the performance for the Vestal eighth grade and the Trumansburg seventh grade on the first two questions on this task. The statistically significant difference between the Trumansburg and Vestal groups seems to indicate that students perform better on this type of evaluation the longer the exposure to the strategy. Trumansburg had begun using the strategy at the beginning of the school year; there was a three month delay in its implementation in the Vestal eighth grade. While we realize that there is a problem of validity of comparing both groups on their performance in Question #3, Table IX.8 shows no statistically significant difference between the two. While any claims that attempt to explain this result must necessarily be very cautious, it does seem to suggest that, even after limited exposure to the "V" strategy, students are able to identify parts of an inquiry

Table IX.6. Comparison of means for Question #1 (Identifying parts of the "V"). Trumansburg - April, 1980; Vestal (8th) - May, 1980.

Group	Week	N	Mean	S.D.	t-value	df	p
Trumansburg	26	75	17.87	1.15	7.82	133	.0001
Vestal	33	80	14.39	3.87			

Table IX.7. Comparison of means for Question #2 (Defining terms of the "V"), Trumansburg - April, 1980; Vestal (8th) - May, 1980

Group	Week	N	Mean	S.D.	t-value	df	p
Trumansburg	26	75	14.23	2.93	3.85	133	.0001
Vestal	33	80	11.92	4.42			

Table IX.8. Comparison of means for Question #3 (Picking out examples of terms of the "V" given a laboratory exercise), Trumansburg - April, 1980; Vestal (8th) - May, 1980.

Group	Week	N	Mean	S.D.	t-value	df	p
Trumansburg	26	75	13.35	3.18	0.703	133	.472
Vestal	33	80	12.89	4.85			

according to "V" terms if they are familiar with the subject content.

While not reported in table form, a breakdown by individual terms of the "V" (e.g., "theory," "records," etc.) showed that the Trumansburg group scored signficantly higher for "objects," "records," "events," "transformations," "knowledge claims," and "focus question." Vestal, on the other hand, was significantly higher than Trumansburg for the one term of "theory." This may reflect the stress placed on scientific theories in that particular science program, and the generally greater emphasis on theoretical models in junior high physical science curriculums. The theoretical structure of the biological sciences was not stressed in the Trumansburg classroom. This was due in part to the descriptive nature of junior high school biology programs that stress descriptions of plant and animal structures, and minimize discussion of broad explanatory theories or principles.

Considering that the Trumansburg seventh grade sample averaged at the 65th percentile on national norms and the Vestal eighth grade group averaged at the 78th percentile, we have further evidence that the "V" mapping strategy can be acquired by seventh grade students as well as eighth grade students. In fact, both groups seemed so successful at this kind of task, and the "V" in general, that there seems to be no reason why the "V" mapping strategy cannot become part of those grade levels.

Conceptual Questions: "Winebottle" Example:

As mentioned earlier, the conceptual questions provided our best means of comparing instructed and uninstructed groups of students relative to their use of the strategies. The major theoretical issues and the problems that had to be overcome are discussed in detail in Section VII of this report. The following is provided to demonstrate the significance of this type of evaluation, and the implications that can be drawn from its administration with both instructed and uninstructed students.

Both the "Winebottle" and "Electricity" examples were tested with eighth grade students in Vestal. In this case, we worked only with two of the four eighth grade instructed classes. For the uninstructed group we solicited the help of another part-time eighth grade teacher who taught two sections in the afternoon. In order to characterize both populations for this, and the "Electricity" example, we performed a *t*-test to compare the means between the instructed and uninstructed groups of their performance on the reading and math parts of their SAT tests. Tables IX.9 and 10 represent the findings of this analysis. With the low *t*-values for the reading (0.69) and the math (0.82) with corresponding probabilities of 0.493 and 0.413 respectively, we can state that there is no statistically significant difference between the two groups in their mean scores for both the reading and math parts of the SAT.

Table IX.9. Comparison of means for SAT reading percentiles for the instructed and uninstructed groups of eighth grade students in Vestal, New York.

Group		Mean	S.D.	t-value	df	p
Instructed	77	78.00	19.96	0.69	117	0.493
Uninstructed	42	75.21	23.08			

Table IX.10. Comparison of means for SAT math percentiles for the instructed and uninstructed groups of eighth grade students in Vestal, New York.

Group	N	Mean	S.D.	t-value	df	p
Instructed	77	78.00	20.51	0.82	117	0.413
Uninstructed	42	74.55	24.26			

The "Winebottle" example was administered to the four groups (two instructed, two uninstructed) in March, 1980. The instructed group had had approximately four months of exposure to concept mapping and the "V" strategies. The students' papers were evaluated in the following manner: for every correct conceptual link that was made between two concepts (e.g., expansion is due to the movement apart of the molecules in a gas), one point was awarded. The number of correct conceptual relationships were then tallied. The number of conceptual links that were incorrect (e.g., the size of molecules increases as heat is added), were tallied as well. Tables IX.11 and IX.12 represent the findings between the instructed and uninstructed on their performance of using correct or incorrect conceptual relationships in their answer to the winebottle example.

Table IX.11. Comparison of means for the number of correct relationships written in the "winebottle" example for both instructed and instructed students; Vestal - March, 1980.

Group	N	Mean	S.D.	t-value	df	p
Uninstructed	42	1.45	1.40	-3.44	86	.001
Instructed	46	2.61	1.71			

Table IX.12. Comparison of means for the number of misconceptions (incorrect relationships) written in the winebottle example for both instructed and uninstructed students; Vestal - March, 1980.

Group	N	Mean	S.D.	t-value	df	p
Uninstructed	42	0.52	0.71	0.32	86	0.749
Instructed	46	0.48	0.62			

Examination of Table IX.11 reveals that students who had training in the use of concept mapping and "V" mapping performed signficantly better on the number of correct relationships used in answering the "Winebottle" example. This leads to the inference that the use of these two strategies can significantly increase the meaningful learning process by providing a means to analyze some event, and then to organize the relevant concepts in such a manner as to "make sense" of the proposed event. Without these strategies, fewer correct conceptual links are made.

What is interesting, though, is the comparison of the number of misconceptions offered by both groups of students in their answers. Table IX.12 shows that there is no statistically significant difference in the means of the number of misconceptions written by both groups. Although concept mapping can be a useful tool for revealing concept misconceptions, we observed little instruction that employed concept mapping as a tool to help students (and teachers) explicate misconceptions and move to identify requisite additional or alternative concept relationships that could result in recognition of and/or uprooting of these misconceptions. Obviously, the degree of meaningful learning that is occurring is not related to the conceptual structure as it is understood by experts in the discipline, but is related to the ability of the student to consciously link new concepts to ones already possessed. This will be discussed further in the next chapter.

Conceptual Questions: "Electricity" Example:

The "electricity" example provided some interesting information for our project group as we attempted to become more sophisticated in this kind of evaluation strategy. In the "winebottle" example, we lumped all the students' conceptual links into two main categories, "correct relationships" and "misconceptions." In this example, we classified the answers into a number of different categories which reflected, we believe, the kinds of conceptual links established by the students in their answers. Section VII reports on the number and identification of these categories.

Here, as in the example previously, the means between the instructed and uninstructed groups of students were compared. Table IX. 13 represents this comparison for each of the four categories of correct "atomic," "electrical," "hypothetical," and "logical" relationships, as well as the mean total number of correct relationships. Table IX.14 represents the comparison of means of the categories of misconceptions, "atomic," and "electrical," as well as the mean total number of misconceptions. Because no "hypothetical" or "logical" misconceptions were recorded, these have been deleted from Table IX.14.

In each of the categories, "atomic" and "electrical," the instructed students performed statistically significantly better than the uninstructed group of students. In the category of "hypothetical" relationships, the uninstructed group performed better than the instructed group. This may indicate that the uninstructed group was more speculative in their attempt to provide an adequate explanation for the electrical event posed in the

Table IX.13. Comparison of means for the number of correct relationships identified by instructed (I) and uninstructed (U) students in the "Electrical" conceptual question. Comparisons for each category and total score. N for instructed and uninstructed are 81 and 42, respectively. Vestal, June, 1980.

Category/Group		Mean	S.D.	t-value	df	p
Atomic	U	0.60	0.59	-2.78	121	0.01
	I	1.03	0.91			
Electrical	U	1.47	1.10	-2.67	121	0.01
	I	2.05	1.14			
Logical	U	0.07	0.26	0.44	121	0.66
	I	0.05	0.27			
Hypothetical	U	0.45	0.80	2.51	121	0.01
	I	0.16	0.49			
Total	U	2.60	1.33	-2.31	121	0.02
	I	3.28	1.68			

Table IX.14. Comparison of means for the number of misconceptions identified by instructed (I) and uninstructed (U) students in the "Electricity" conceptual question. Comparison for categories of "atomic," "electrical" and total. N for instructed and uninstructed were 81 and 42, respectively. Vestal, 1980.

Category/Group		Mean	S.D.	t-value	df	p
Atomic	U	0.41	0.59	0.64	121	0.53
	I	0.33	0.59			
Electrical	U	0.17	0.44	-1.21	121	0.24
	I	0.30	0.62			
Total	U	0.57	0.80	-0.36	121	0.72
	I	0.63	0.87			

question to the students. In the category of "logical" relationships, the two groups showed no statistically significant difference. Further, in the categories of misconceptions of "atomic" and "electrical" principles, no significant differences were found between the two groups.

These findings seem to corroborate what was already determined in the "winebottle" example: instruction in the strategies of concept mapping and the "V" had some effect on meaningful learning of concepts, and that these students are able to make the conceptual links better than students who were uninstructed.

With the category of "logical" principles, no significant difference was found between the two groups. The logic skills may be independent of subject matter, or they may be dependent upon years of accumulated cognitive development, and hence, do not show change over the comparatively short duration of the study (see Novak, 1977a, Chapter 8).

As in the previous example, there is no difference between the number of misconceptions written by both the uninstructed and instructed groups. Again, the strategies of concept mapping and "V" mapping appear only to organize what the student believes are the relationships among the concepts they possess, but do not necessarily distinguish between conceptual links that are correct or incorrect. While the strategies may help students and teachers to see misconceptions, there were no explicit instructional efforts to reconcile these misconceptions.

In the "winebottle" example described earlier, all the instructed students made concept maps prior to answering the question posed. In the "electricity" example, half the instructed group was asked to make a concept map while the other half was not asked to make a concept map.

The entire group of instructed students was composed of four classes that met with that teacher every day. These classes were selected at random to prepare or not to prepare concept maps prior to constructing their answers. There is no reason to believe that the classes were significantly different from each other, since the policy of the Vestal schools was to achieve heterogeneous classes.

The intention of this inquiry was to determine whether the task of answering the question posed was related to the making of a concept map immediately prior to the task, or whether the strategy had "done its job" already and would not be necessary for the new task. In other words, had meaningful learning, facilitated by the use of the cocept mapping and "V" mapping strategies, been accomplished before the administration of this kind of evaluation instrument. Table IX.15 and IX.16 represent the analysis of the comparison of the means for those instructed students who made concept maps and those who did not for the number of correct relationships in each of the four categories and for the two categories of misconceptions.

Examination of the data reveals that in only one category (correct "hypothetical" relationships, Table IX.15) is there any statistically significant difference between those students who made a concept map as part of the evaluation task, and those who did not. This seems to indicate that the making of a concept map immediately prior to the evaluation task is of no substantial value. Rather, the importance of using concept mapping comes during the regular instruction. This is

Table IX.15. Comparison of means for the number of correct relationships identified by instructed students who made concept maps (Yes) and those who did not (No) in the "Electrical" conceptual question. Comparisons for each category. N for those who made a concept map and those who did not are 41 and 40, respectively. Vestal, June, 1980.

Category/Sub-Group		Mean	S.D.	t-value	df	p
Atomic	No	0.95	0.71	-0.73	79	0.47
	Yes	1.10	1.07			
Electrical	No	2.18	1.11	0.98	79	0.33
	Yes	1.93	1.17			
Logical	No	0.10	0.38	1.69	79	0.10
	Yes	0.00	0.00			
Hypothetical	No	0.28	0.64	2.14	79	0.04
	Yes	0.05	0.29			

Table IX.16. Comparison of means for the number of misconceptions identified by instructed students who made concept maps (Yes) and those who did not (No) in the "Electricity" conceptual question. Comparisons for categories of "atomic" and "electrical" only. N for those who made a concept map and those who did not are 41 and 40, respectively. Vestal, June, 1980.

Category/Sub-Group		Mean	S.D.	t-value	df	p
Atomic	No	0.43	0.68	-1.39	79	0.17
	Yes	0.24	0.50			
Electrical	No	0.35	0.74	0.77	79	0.45
	Yes	0.24	0.49			

consistent with our thesis that concept maps are heuristic devices, needed only to facilitate meaningful learning. Once the meaningful learning has occurred, the construction, or re-construction, of a concept map may not be necessary. Indeed, it may be a duplication of effort and result in negative motivation.

School Measurement of Achievement:

Conventional science tests are, of course, used in both Trumansburg and Vestal to track students' progress. Since there is only one seventh grade science teacher at Trumansburg, we sought to compare achievement scores for students in seventh and eighth grade classes in the larger Vestal school. Also, a comprehensive final examination test is administered to each science grade, and these scores could be used for comparison purposes. This final examination requires almost exclusively recall of specific knowledge, so the evaluation objective is substantially different from what we were doing with concept maps and the "V" strategy.

Since we were working with only one of the four seventh grade teachers and one of the four eighth grade teachers in Vestal, some comparisons can be made. The average of the final examination for the experimental students in the seventh grade was 86.51%; for the entire seventh grade is was 81.92%, showing a difference of almost five points. For the eighth grade, the experimental students' average on this examination was 82.15%; for the entire eighth grade, 82.04%, indicating no large difference between the two groups.

From this, we can see that the introduction of the strategies of concept mapping and the "V" appears to have no substantial effect on the performance of students with respect to conventional classroom and/or school-wide evaluation. We will show below that correlation analysis supports the claim that our evaluation strategies are measuring something substantially different from school achievement test and typical standardized achievement test.

Correlation Analysis:

To see if there are patterns among the various elements or variables that formed the basis of the evaluation for the "Learning How to Learn" Project, and other more conventional achievement measures, a correlation matrix was run for thirteen of these variables. Tables IX.26 through IX.29 show the correlation matrices for the variables studied. These are divided into four broad categories -- scores for concept mapping and the "V", conceptual question, standardized tests, and final achievement grades -- to make the matrices easier to examine.

The task of concept mapping, represented by the total percentage scores in relation to a baseline map, correlated significantly with the ability to identify, define, and pick out examples of terms of the "V" (0.36, P= 0.001). Concept mapping was not correlated, however, with performance on the "V" for laboratory exercises (0.07, P=0.53). The data suggest that concept mapping involves different kinds of cognitive operations than does using the "V".

Correlations between concept mapping scores and conceptual questions was not significant, ranging around the value of 0.00. This suggests that different cognitive performances are required in the two tasks and, therefore, we see these evaluation tools as complementary rather than redundant.

In relation to standardized scores, ability to construct concept maps has essentially zero correlation with SAT scores (Reading, -0.20; Math, 0.02), but a significant correlation with SCAT scores (Verbal, 0.34; Quantitative, 0.31) suggesting that the SAT and SCAT test measure somewhat different cognitive performances. Relative to final grade and final

Table IX.17. Correlation matrix for Concept Mapping scores, Identifying, Defining, and Giving examples on the "V", and scores for Laboratory Exercises using the "V" against other categories of data. Top number is the correlation coefficient; the middle number represents the significance level; the bottom number, in parentheses, represents the size of the sample for analysis. An asterisk (*) indicates that no records were collected to compare those variables.

	Total Score on Concept Maps	Identifying, Defining and examples on the "V"	Laboratory Exercises using the "V"	Total number of correct relationships - "Winebottle" example	Total number of misconceptions - "Wine-bottle" example	Total number of correct relationships - "Electricty" example	Total number of misconceptions - "Electricity" example	SAT - Reading %tile	SAT - Math %tile	SCAT - Verbal	SCAT - Quantitative	Final Examination Grade	Final Course Average
Total Score on Concept Map	---	0.56 0.0001 (119)	0.07 0.529 (75)	0.04 0.791 (43)	0.10 0.523 (43)	0.16 0.180 (76)	-0.01 0.901 (76)	-0.02 0.815 (146)	0.23 0.784 (146)	0.34 0.0005 (101)	0.32 0.001 (101)	0.20 0.796 (156)	0.11 0.162 (157)
Identifying, Defining, and Examples on the "V"	0.56 0.0001 (144)	---	0.41 0.0001 (74)	0.09 0.570 (46)	0.09 0.576 (46)	0.51 0.002 (78)	-0.19 0.105 (78)	0.30 0.0003 (147)	0.33 0.0001 (147)	*	*	0.24 0.002 (158)	0.39 0.0001 (159)
Laboratory Exercises using the "V"	0.07 0.529 (75)	0.41 0.0001 (71)	---	*	*	*	*	0.52 0.0001 (79)	0.54 0.0001 (79)	*	*	0.53 0.0001 (81)	0.63 0.0001 (82)

Table IX.18. Correlation matrix for Correct Relationships and Misconceptions for "Winebottle" and "Electricity" examples of Conceptual Questions against other categories of data. Top number is the correlation coefficient; the middle number is the significance level; the bottom number, in parentheses, represents the size of the sample for analysis. An asterisk (*) indicates that no records were collected to compare those variables.

	Total Score on Concept Maps	Identifying, Defining, and Examples on the "V"	Laboratory Exercises using the "V"	Total number of correct relationships - "Winebottle" example	Total number of misconceptions - "Winebottle" example	Total number of correct relationships - "Electricity" example	Total number of misconceptions - "Electricity" example	SAT - Reading %tile	SAT - Math %tile	SCAT - Verbal	SCAT - Quantitative	Final Examination Grade	Final Course Average
Total correct relationships "Winebottle"	0.41 0.790 (43)	0.09 0.572 (46)	*	---	-0.28 0.009 (88)	-0.26 0.120 (83)	-0.26 0.016 (83)	0.43 0.0001 (80)	0.39 0.0003 (80)	*	*	0.31 0.055 (46)	0.40 0.006 (46)
Total of misconceptions "Winebottle"	0.20 0.320 (43)	-0.09 0.576 (46)	*	0.28 0.009 (88)	---	-0.16 0.147 (83)	0.22 0.044 (83)	-0.03 0.776 (80)	-0.06 0.574 (80)	*	*	-0.10 0.498 (46)	-0.27 0.075 (46)
Total correct relationships "Electricity"	0.16 0.180 (76)	0.31 0.002 (78)	*	0.26 0.020 (83)	0.16 0.117 (83)	---	-0.19 0.040 (123)	0.25 0.007 (110)	0.36 0.0001 (110)	*	*	0.27 0.015 (81)	0.32 0.004 (81)
Total of misconceptions "Electricity"	0.01 0.900 (76)	-0.19 0.105 (78)	*	-0.26 0.016 (83)	0.22 0.044 (83)	0.19 0.040 (123)	---	-0.12 0.222 (110)	-0.15 0.132 (110)	*	*	-0.30 0.015 (81)	-0.28 0.012 (81)

Table IX.19. Correlation matrix for Standardized SAT and SCAT scores against other categories of data. The top number is the correlation coefficient; the middle number represents the significance level; the bottom number, in parentheses, represents the size of the sample for the analysis. An asterisk (*) indicates that no records were collected to compare those variables.

	Total Scores on Concept Maps	Identifying, Defining, and examples on the "V"	Laboratory Exercises using the "V"	Total number of correct relationships - "Winebottle" example	Total number of misconceptions - "Winebottle" example	Total number of correct relationships - "Electricity" example	Total number of misconceptions - "Electricity" example	SAT - Reading %tile	SAT - Math %tile	SCAT - Verbal	SCAT - Quantitative	Final Examination Grade	Final Course Average
SAT Reading %tile	-0.02 0.810 (116)	0.30 0.0003 (147)	0.52 0.0001 (79)	0.45 0.0001 (80)	0.03 0.776 (80)	0.25 0.007 (110)	-0.12 0.0001 (110)	---	0.77 0.0001 (200)	*	*	0.74 0.0001 (155)	0.71 0.0001 (156)
SAT Math %tile	0.02 0.781 (116)	0.33 0.0001 (147)	0.54 0.0001 (79)	0.39 0.0003 (80)	-0.06 0.571 (80)	0.36 0.0001 (110)	-0.15 0.131 (110)	0.77 0.0001 (200)	---	*	*	0.70 0.0001 (155)	0.77 0.0001 (156)
SCAT - Verbal	0.31 0.0005 (101)	*	*	*	*	*	*	*	*	---	0.63 0.0001 (185)	*	*
SCAT Quantitative	0.32 0.001 (101)	*	*	*	*	*	*	*	*	0.63 0.0001 (185)	---	*	*

Table IX.20. Correlation matrix for Final Examination scores and Final Course Averages against other categories of data. The top number is the correlation coefficient; the middle number represents the significance level; the bottom number, in parentheses, represents the size of the sample for analysis. An asterisk (*) indicates that no records were collected to compare those variables.

	Total Score on Concept Maps	Identifying, Defining, and examples on the "V"	Laboratory Exercises using the "V"	Total number of correct relationships - "winebottle" example	Total number of misconceptions - "winebottle" example	Total number of correct relationships - "Electricity" example	Total number of misconceptions - "Electricity" example	SAT - Reading %tile	SAT - Math %tile	SCAT - Verbal	SCAT - Quantitative	Final Examination Grade	Final Course Average
Final Examination Grade	0.02 0.796 (156)	0.24 0.0024 (158)	0.55 0.0001 (81)	0.31 0.035 (46)	0.10 0.498 (16)	0.27 0.015 (81)	-0.30 0.0058 (81)	0.74 0.0001 (155)	0.70 0.0001 (155)	*	*	---	0.84 0.0001 (170)
Final Course Average	0.11 0.162 (157)	0.39 0.0001 (159)	0.63 0.0001 (82)	0.45 0.006 (46)	0.27 0.746 (16)	0.32 0.004 (81)	-0.28 0.012 (81)	0.71 0.0001 (156)	0.78 0.0001 (156)	*	*	0.84 0.0001 (170)	---

examination scores, concept mapping shows a low correlation (0.20, P=0.08; 0.11, P=0.16, respectively). These low correlations indicate that conventional school achievement measures do not measure what we regard as important aspects of science education that might be better assessed with the use of concept maps and "V" maps.

Two forms of evaluation of the "V" were performed: identifying, defining, and picking out examples of terms of the "V" and using the "V" for laboratory exercises. The correlation coefficient and significance level for these two are 0.44 and P=0.0001, suggesting a strong relationship. Unfortunately, the entire source of laboratory exercises using the "V" came from Trumansburg, and the conceptual questions administered there possessed enough difficulties to preclude their use in the analysis. Thus, no correlations were computed between "V" mapping scores and conceptual questions. For both aspects of the "V", there is a high correlation between each and performance on the SAT, both reading and math. Similarly, high correlations exist between both aspects of the "V" evaluation and final examination grades (0.24 and 0.53, respectively) and final average grades for the year (0.39 and 0.63).

In general, the correlation tables support the conclusion that the evaluation strategies used account for substantially different cognitive performances than school achievement tests and standardized achievement tests, with only some 4% to 38% of shared variance between these measures. These data may account in part for the fact that school achievement does not necessarily reflect future interest and success in science careers.

X. CLAIMS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Major Claims of the Four Research Questions:

The discussion of the major knowledge claims of the "Learning How to Learn" Project will follow the format of the original four research questions that were asked in Section I of this report. After these questions have been answered, a list of recommendations for future research will be discussed. In addition to these recommendations, it should be remembered that Sections V and VI discussed caveats concerning the introduction of concept mapping and the knowledge "V" into the classroom. These should be consulted as well.

CAN SEVENTH AND/OR EIGHTH GRADE SCIENCE STUDENTS LEARN TO USE THE CONCEPT MAPPING AND THE "V" MAPPING STRATEGIES IN CONJUNCTION WITH EXISTING SCIENCE PROGRAMS.

There appeared to be enough accumulated evidence that supports the claims that junior high science students can indeed acquire the strategies of concept mapping and "V" mapping, and that they can utilize them for their readings and their laboratory exercises. The introduction of these strategies into the classroom takes little time away from the conventional curriculum while potentially increasing the meaningful learning process, thereby making the learning of the content material of the course more efficient. Although students with higher ability, as assessed through standardized achievement tests and classroom evaluation, perform at a higher level of compentence with these strategies, high performance was also demonstrated by significant numbers of students in lower quartiles on standardized tests.

With respect to concept mapping, the students appeared to like to use this strategy because it allowed them to "pick apart" a piece of text reading or some other study material and to construct relationships among the concepts presented. This was evidence that more leaningful learning was occurring, since there was a conscious effort on the part of the learner to find the relationship of one concept to another. The mechanics of making a concept map presented no major difficulties to the students. They appeared to understand well the ideas of "conceptual relations" and "hierarchy," but had more difficulty constructing "cross links." This may be due in part to the nature of the instructional materials, most of which present information in a linear fashion with little effort to show interrelationships among concepts and to refer back to relevant ideas presented earlier.

Generally, students improved over time in their ability to construct concept maps. Sixty-four percent of the students tested twice during the 1979-1980 school year were able to increase their total score by at least 25%. We believe that by making the rules for constructing concept maps more explicit to the students, we can anticipate an increase in concept map scores, probably approaching "mastery" after some period of time for all students who complete assignments. As with any school work, some students made little effort to construct concept maps or "V" maps.

It shouldbe remembered also that the amount of time on task involving concept mapping (and also the knowledge "V") was estimated to be only between 5 - 15% of class time. Differences that existed in performance measures for the concept mapping strategy favored the Trumansburg group (7th grade), and might be due to their greater amount of time on task. In any event, it is gratifying that most students performed at a high level of competence with such limited exposure.

The Knowledge "V" can be used by students to represent the laboratory exercises they perform in class, and to relate the conceptual and methodological sides of any inquiry. Generally, students found the "V" harder to do than concept mapping, but that might be due to having to "juggle" so many different terms in their minds: What is the event here? What are the principles and concepts? How should I word the focus question?

Another possible reason for students having more difficulty with the "V" mapping deals with teacher expectations from the students. The "V's" that most of the students made were completed after they had already written conventional laboratory reports for the teacher. Since the laboratory report was written twice, students saw this as a duplication of effort. That is not a popular position with junior high students.

This notwithstanding, students did report, and the evidence seems to support this, that the "V" helped them to determine what the lab was all about, and helped them to separate what was needed to be known from the lab. We believe that even this is a significant step to understanding the role that concepts play in any inquiry, and indicates that a more meaningful learning of content material is occurring.

As with concept mapping, the criteria for assessing students' "V's" should be made explicit to the learners. We believe that this is the reason that students' "V's" began to hover around the tweleve to fourteen range of scores during the latter part of the project, rather than moving toward the maximum of eighteen on our scale. If students had been told what counts, for instance, as a good focus question, and had been given clear cases for each of the levels from zero through three, students probably could have improved in each of the five categories of criteria.

The scope of our study was limited; all the evidence that we have acquired on using the "V" for laboratory exercises came from one school. Differences in teachers, students, and programs would have been a fruitful medium for exploring the range of "V" mapping performances, and this should be part of future research studies.

There must also be a consideration of the term "existing school program" as identified in the research question. Although no evidence is reported, there was a growing impression by the staff over the two year period that many of the curriculums with which we became familiar were seriously deficient in the conceptualizations of the subject matter. All too often, we found gapping "holes" in the laboratory exercises, or where the text presumed that the learner knew more than what he/she actually did. Reading passages, which were identified as answering some question often did not answer that question at all, but rather led the student off on a descriptive tangent of some other event or experience. So to say that these strategies can be used in conjunction with conventional curriculums warrants a qualification. Teachers who adopt these strategies and their theoretical foundations must be wary of the limitations of text and curriculum.

WILL STUDENTS' ACQUISITION OF SCIENCE KNOWLEDGE AND PROBLEM SOLVING PERFORMANCE CHANGE AS A RESULT OF THE STRATEGIES?

We must be careful to identify what kinds of knowledge we are discussing, and how students' performances are evaluated. If we discuss the acquisition of science knowledge (as noted in the question), that is, the relationships among the conceptualizations of the fields of science and their relevance for making sense of events, we can state that the introduction of the strategies has facilitated the meaningful learning of those conceptualizations and their relations to events. If, however, it is knowledge about knowledge that is being discussed, our case is less convincing. We are less confident that students and teachers, as well, have acquired in any meaningful way these "meta-" concepts about knowledge and the knowledge-making process. This is most likely due to a lack of familiarity about the strategies and the epistemological and psychological principles that formed the basis of the project.

But this does not imply that there is no evidence that "meta-" concepts could have been acquired. While one of the most important aspects of the strategies is that they caused students to begin to understand the subject matter in a more meaningful way, there seems to be some suggestion that concept mapping and "V" mapping facilitated also the understanding of the structure of knowledge in the science field. As students made concept maps, they had to identify the most inclusive concept of the reading, illustrate its relationships to subordinate concepts, and then show these relationships through the lines drawn among them. Given that, students acquired a deeper understanding of the relationships among the concepts in a subject matter, even though it is doubtful whether they had actually articulated any "meta-" concepts about the structure of knowledge.

When we turn to concepts about learning, that is, "meta-learning," we are even less confident. Although the project teachers did present the activities from the Teacher's Handbook (Appendix I, Section II) to the students, there is no clear evidence that the principles generated from those activities became operational in the classroom. In all of the clinical interviews and more informal interviews we conducted with students and teachers, and all the classroom visitation we made, no evidence exists that the teachers were utilizing these learning principles in their classes.

We must also be careful when discussing student performance relative to the type of evaluation instrument used to determine whether there has been an acquisition of science knowledge. In terms of conventional classroom evaluation, we found no significant difference between the instructed groups of students and the uninstructed in the same school and grade in relation to performance on district-wide final examinations. But we believe that these examinations attempted to assess something very different than our objectives in this project. Inspection of these final examinations led to the conclusion that they were seriously deficient in linking concepts in the subject matter, and appeared to require only rote learning to perform well. When we turn to student performance on our own conceptual questions, whose design utilized the strategies of concept mapping and the "V", we found significant differences between instructed and uninstructed students. The strategies, it is claimed, assisted the students in organizing their conceptual understanding of the subject matter, and utilized that organization to make sense of some new event. Thus, the evidence suggests that conceptual questions have tapped the students' cognitive structures to see the comparative degree of meaningful learning.

If we define problem solving as the ability to offer an explanation to an event using concepts that the student has learned in a meaningful way, then our conceptual questions can become an important aspect of the problem solving evaluation of students. Although there is much research to be conducted with these conceptual questions, there is signficant knowledge now that suggests that this form of evaluation has important ramifications for the evaluation of student understanding of the subject matter.

One point needs to be made in relation to these conceptual questions, and the use of the strategies of concept mapping and "V" mapping. While our evidence shows that the strategies can be taught to students, and that conceptual questions are a form of evaluation to test for meaningful learning, the use of the questions cannot alone rectify misconceptions that exist in the students' cognitive structures. The strategies are tools for organization to assist in meaningful learning, so their employment without careful attention to the misconceptions of the students will not automatically reconcile these misconceptions. In other words, there is no substitute for good teaching.

Does performance on conceptual questions increase as the student is exposed to this evaluation strategy? It might be expected that students, having become familiar with the evaluation task, would improve over time. Although the evidence from the "Winebottle" and "Electricity" examples showed no significant change from the first to the second conceptual question for those experimental students who had both, we believe that given enough instruction consistently over a period of time in the strategies and employing conceptual questions as part of conventional classroom evaluation (tests, homework, laboratory exercises), we can expect a positive difference in student performance on this type of evaluation.

IS THERE A SHIFT TOWARD A MORE POSITIVE ATTITUDE ABOUT SCIENCE CLASS AS A RESULT OF THE INTRODUCTION OF THESE STRATEGIES?

From the data that was collected during the second year of the project, the evidence is inconclusive to answer this question. Two forms of evaluation were done to determine whether students became more positive in their attitudes about science class. The eighteen item questionnaire, we believe, might indeed probe some of the feelings that students have about science class, reading, laboratory work, and the nature of science, but there are many other factors that might affect the validity of any claim to be drawn from the results of such an assessment. For instance, does the shift toward a more positive attitude about science class increase as students' exposure to the strategies increase? How much is teacher personality affecting the results? How much is the presence of friends (and adversaries) in the class affecting the attitudes? Is the program laboratory-oriented or more didactically presented? What is the general milieu of the school? Of the class? How important to the student, his parents, to the community in general is a good science program in the school? What kinds of science programs existed at the elementary level, and what effect do they have on student attitude? All of these, taken individually or taken collectively, might have some effect on the attitudes that students have about science class. Much more sophisticated assessments of affective factors would be needed than was possible in this research project.

Fortunately, however, there are some other sources, more direct than questionnaires, that can be used to assess students' feelings about these strategies: we can ask them how they feel. In the clinical and informal interviews conducted with the students during the last year of the project, we had the opportunity to ask students how they felt about concept mapping and the knowledge "V", and whether they saw any value for them in their science class. Although concept mapping received better reviews than the "V", generally most students thought that both had helped them in their understanding of the subject material. But whether improved understanding of the subject material is related to attitudes in general about science class remains to be studied further.

CAN CLASSROOM TEACHERS BE TAUGHT TO INSTRUCT PUPILS IN THE PROPER USE OF THESE STRATEGIES?

The answer to this question has to be a qualified "yes." It must be remembered that the strategies of concept mapping and "V" mapping involve several levels of understanding: concepts of learning, concepts of teaching, concepts of the structure of knowledge, and concepts of the knowledge-making process.

For the teachers in our pilot study, we believe that they had attained some comprehension of the strategies as organizational and diagnostic tools, thereby becoming important aspects of teaching. Concept mapping could be used as a means to represent the concepts and their relationships that are presented in the text. As a diagnostic tool, concept mapping could be used to represent the meanings that students ascribe to concepts. Similarly, the "V" strategy provides the teacher with a quick overview of a laboratory exercise to organize the conceptual side from the methodological side, and provides clarity with respect to the intention of the exercise (focus questions and events). The "V" can be used to visually represent where students went wrong in their laboratory exercises, or what concepts were not used as part of the left-hand side of the "V".

However, relative to using the strategies to foster concepts of learning, knowledge-making, and the structure of knowledge, our evidence is scant to say that teachers had acquired this level of understanding. There can be many reasons for this, some of which have already been mentioned in the preceding sections. Teachers are very busy people. As such, there is little time, given all the duties that they perform, to sit back and reflect on the ideas of this kind of project. Unfortunately, this situation necessitates a sort of "shoot from the hip" approach to any new ideas, or forgetting the new idea in favor of older tried and true methods.

Second, in the two years of the project there was no forum to teach the teachers the major epistemological and psychological foundations of the project. As mentioned earlier, fully two-thirds of the two years of the project involved refining the pedagogical strategies, based upon the theoretical foundations. A large turn-over of project staff also compounded the difficulties. This, coupled with no opportunity to work with teachers in a leisurely pace with these ideas, say a two day workshop away from the home school, resulted in limited understanding of the theory behind the strategies.

We do not wish to imply that the teachers working with us were uncooperative or limited in talent. Indeed, the opposite was true. Every teacher we have worked with often sparkled with enthusiasm and all would have to be regarded as superior in terms of knowledge of science, and talent in working with children. We, the project staff, were struggling with finding practical ways to implement teaching strategies derived from a psychology of learning and a philosophy of knowledge that was only marginally comprehended by many of us: we too were learners! The remarkable fact is that the teachers were so good, so successful in working with us when we were learning how to "get our act together." We believe our experiences, as reflected in this report and in the Teacher's Handbook will make it possible for teachers with comparable educational skills, or perhaps even less, to achieve a large measure of success with these strategies.

Thus, we are optimistic regarding the improvement of science teaching. There can be significant changes in the levels of conceptualizations about teaching, learning, knowledge, and curriculum if only the forum were provided for teachers. Recent work at Cornell University with a modification of Kagan's (1975) Interpersonal Process Recall (IPR), suggests that teachers can indeed change their conceptualizations about teaching even with the very busy schedule and within a comparatively small time committment (Way, 1981).

Recommendations for Future Research:

Several recommendations for future research have already been mentioned in various sections of this report. For the sake of brevity and conciseness, though, they are included in this last section.

1. It was remarkable to the staff that students performed so well with these strategies relative to the small amount of time on task. Further, use of these strategies were limited to one teacher during the course of one school year. It would be enlightening to determine what effects would accrue with a horizontal introduction of these strategies across subject areas, and longitudinally across grade levels. Perhaps one year's, one subject's exposure to the strategies is not enough. Could a school using a team approach adopt these strategies in their English, science, social studies, and math classes? Of course, the nature of the knowledge in each of these areas would necessarily be different, but that does not dismiss the idea that each is a field that conceptualizes about some events, and that each field has a structure of its own knowledge. Longitudinally, students could be introduced to concept mapping as early as first grade. Work in progress in Australia by the project director has demonstrated that is is feasible. While the "V" might be postponed until later, elementary students should be able to grasp key epistemological ideas and later to use Gowin's "V". Repeated exposure to these strategies over several years could lead to significant changes in learning, and students' perception of the nature of knowledge and the nature of rational thought (Novak, 1980).

2. A second recommendation deals with the structure of "conventional" curriculums and the adoption of these strategies to fit into that curriculum. Although we have found that the strategies can be incorporated into existing school science programs, we believe that a re-conceptualizations of the curriculum is necessary to effect the full power of the concept mapping and the "V" mapping strategies. Some work, involving the reorganization of curriculums to a psychological organization, has already begun with staff members who have returned to teaching during the 1980-1981 school year. Research is now being conducted to psychologically and epistemologically orient students in three separate areas: chemistry, the IPS Program, high school biology, and an animal behavior course.

3. It should be evident that the teacher's knowledge is also important. We cannot expect that students will be able to arrive at higher levels of conceptualization about learning, the structure of knowledge, and the knowledge-making process if the teachers have not been taught to recognize such order. Thus, the preparation of the teacher must be improved substantially. Again, this year, preliminary research to determine if teachers can be taught to restructure their previous knowledge, as well as to acquire the techniques for teaching the learning strategies is now being investigated. This is a new set of challenges, requiring much extensive research, and we need colleagues to join with us.

4. Students participating in the "Learning How to Learn" Project were higher ability students than we had originally suspected. Correlations between ability, as measured by standardized achievement tests, and performances with concept mapping and the "V" do indicate a strong positive relationship between the two variables. However, the evidence is also encouraging that a significant number of lower ability students can acquire and use these strategies. Given this, a replication project needs to be conducted to see how effective these strategies are with these lower ability students.

5. Concept mapping and "V" mapping provide a powerful new evaluation strategy, once students are taught to use these tools. The data from this study indicates that these evaluation tools are reliable and valid and that they tap substantially different abilities than conventional achievement tests.

6. We believe that the creation of conceptual questions can provide a powerful means for evaluation of meaningful learning, and which can be adopted in any classroom. However, with only two examples for our evidence, no matter how encouraging that evidence might be, further research should be conducted which attempts to determine if there is any improvement over time in students' ability to answer this type of question. This can be done over the course of a single year, or longitudinally where students have been presented new material without the assistance of concept mapping and the "V". Some research in this area is also being conducted this year.

7. As mentioned in Section VI of this report, the use of the "V" was restricted to knowledge claims with no research relative to the value claims of science. This we believe is an important aspect of science education, but was beyond the resources of this present project. We recommend, therefore, that future studies, whenever possible, include the idea of value claims together with the other concepts of Gowin's "V".

8. There is a need for research on classroom climate and the possible effect of "learning how to learn" strategies on teacher-pupil relationship.s The work begun by Way (1981) with college students could serve as a model for elementary and secondary schools.

In conclusion, we believe the research reported here shows promise for a brighter future in education. The practical strategies represented in concept mapping and Gowin's "V" is derived from a theory of education, and as such, the technology is both guided by and will serve to modify and improve the theory. Theory-based educational strategies have not been common in educational history, and therefore we have hope for progressive, evolutionary development of both educational theory and derivative, practical teaching strategies that may improve human understanding.

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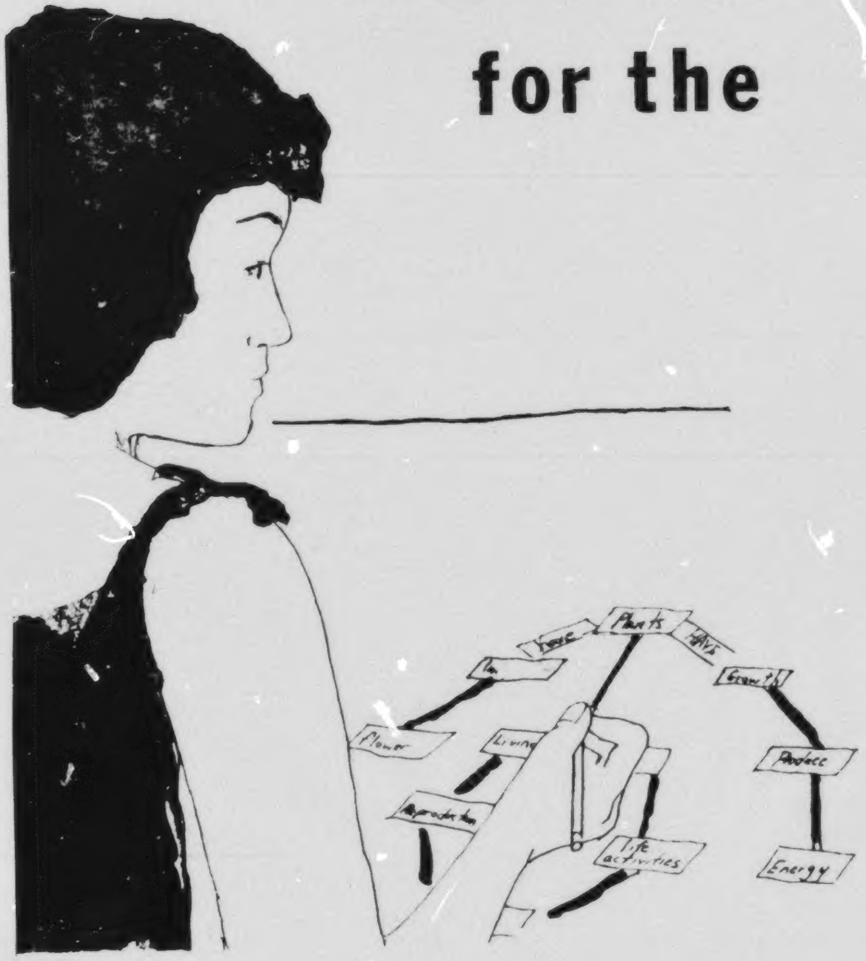
APPENDIX I

Teacher Handbook for the "Learning How to Learn" Project

TEACHER
HANDBOOK
for the


Plants
have
HAVE
Growth
Flower
Living
Produce
Reproduction
Life activities
Energy

LEARNING HOW TO
LEARN PROGRAM

New York State College of Agriculture and Life Sciences
Cornell University, Department of Education
103 Stone Hall, Ithaca, NY 14853

HANDBOOK FOR THE LEARNING HOW TO LEARN PROGRAM

Supported in part by grants from the National Science Foundation
(SED 78-16762) and Shell Companies Foundation

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To the students of Trumansburg, Vestal, Lansing, Homer, and Ithaca for all their work on our behalf. Anyone involved in education knows that the student is our most severe critic. We hope that we have given them as much as they have helped us.

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Several drafts of this handbook were prepared by Gerry Johansen who also coordinated staff efforts during the 1979-1980 school year.

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Cover Design by Fred Wendell

I. INTRODUCTION

MEANINGFUL LEARNING

THE KNOWLEDGE "V"

CONCEPT MAPPING

MEANINGFUL LEARNING

The "Learning How to Learn Program" is designed for use in any classroom together with the regular program of instruction. Although the materials in this handbook were prepared for junior high science teachers, they might be used by teachers at other grade levels and in other subject matter fields.

To understand how to become a better learner, students need to gain some understanding of (1) the learning process, (2) the nature of knowledge, and (3) how to extract meanings from materials studied. This program is based on Ausubel's (1978) cognitive learning theory which places emphasis on the difference between meaningful learning and rote learning. In fact, the major objective of this program is to help students learn how to learn meaningfully. To acquire knowledge meaningfully means that the learner must incorporate new knowledge into concepts that the learner already has. Our program is designed to extend, modify and elaborate these concepts, partly through providing instruction in new relationships among the concepts that the student already has and partly by providing new relevant concepts about learning.

THE KNOWLEDGE "V"

We have found that students gain in their understanding of meaningful learning when they acquire knowledge about the knowledge-making process. To accomplish this, we have found a simple device invented by Gowin (1979) to be helpful. We teach students to understand each of the elements represented on Gowin's "V" shown in Figure 1.* At the "point" of the "V" are objects and events, and these occur in the natural world or are made to occur by people (as in a laboratory experiment). At this point, our key conceptual activities come together with our methodological activities. We define a concept as a regularity in

*A more extensive treatment of the "V" and its accompanying terms can be found in section IV in this handbook.

events or objects designated by a sign or symbol. For instance, to study digestion of starch by saliva, we need concepts of enzyme, starch, digestion, maltose, sugar, solution, and others. Students begin to see that even to set up a meaningful experiment, or to be selective in observing objects and events, we must use concepts.

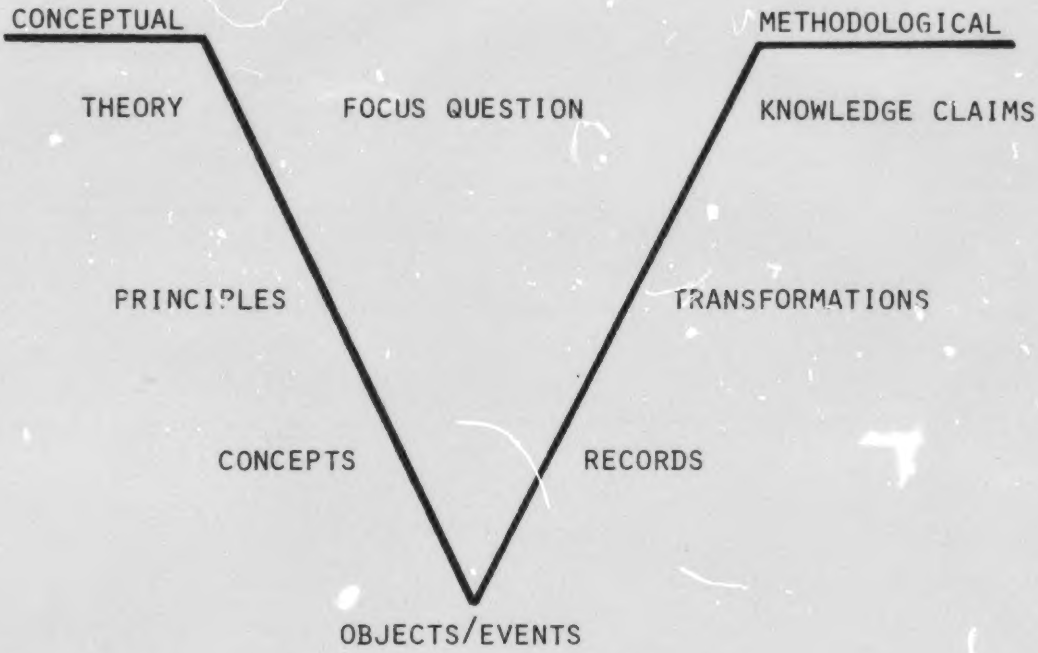
CONCEPTUAL
METHODOLOGICAL
THEORY
FOCUS QUESTION
KNOWLEDGE CLAIMS
PRINCIPLES
TRANSFORMATIONS
CONCEPTS
RECORDS
OBJECTS/EVENTS

Figure 1. Gowin's Knowledge "V" (1979) used with seventh and eighth grade students as a heuristic device to help in understanding how knowledge is produced in the sciences.

The V-shape of this device serves to emphasize that both conceptual and procedural or methodological elements are brought to bear on objects and events in the process of knowledge production. A "focus question" serves to direct the process of knowledge production.

Concepts can be linked together to describe a specific regularity, such as, "the sun rises every morning." This kind of statement or proposition is often called a principle. Principles, in turn, may be related together in broader, more inclusive ideas that we call theories, such as the atomic theory or the theory of natural selection.

Concepts, principles, and theories also guide the methodological activities on the right-hand side of the "V". These activities include record-making, such as gathering instrument readings or notes on observations, and transformations, such as graph or chart preparations or statistical analysis. The knowledge claims represent what has been constructed through the active interplay among the concepts, principles, and theory we use and the records and transformations about the events and objects we have examined.

CONCEPT MAPPING

Another device we have found useful is to have students construct concept maps. Concept maps help students understand that concepts derive their meanings through "connections" or relationships with other concepts.

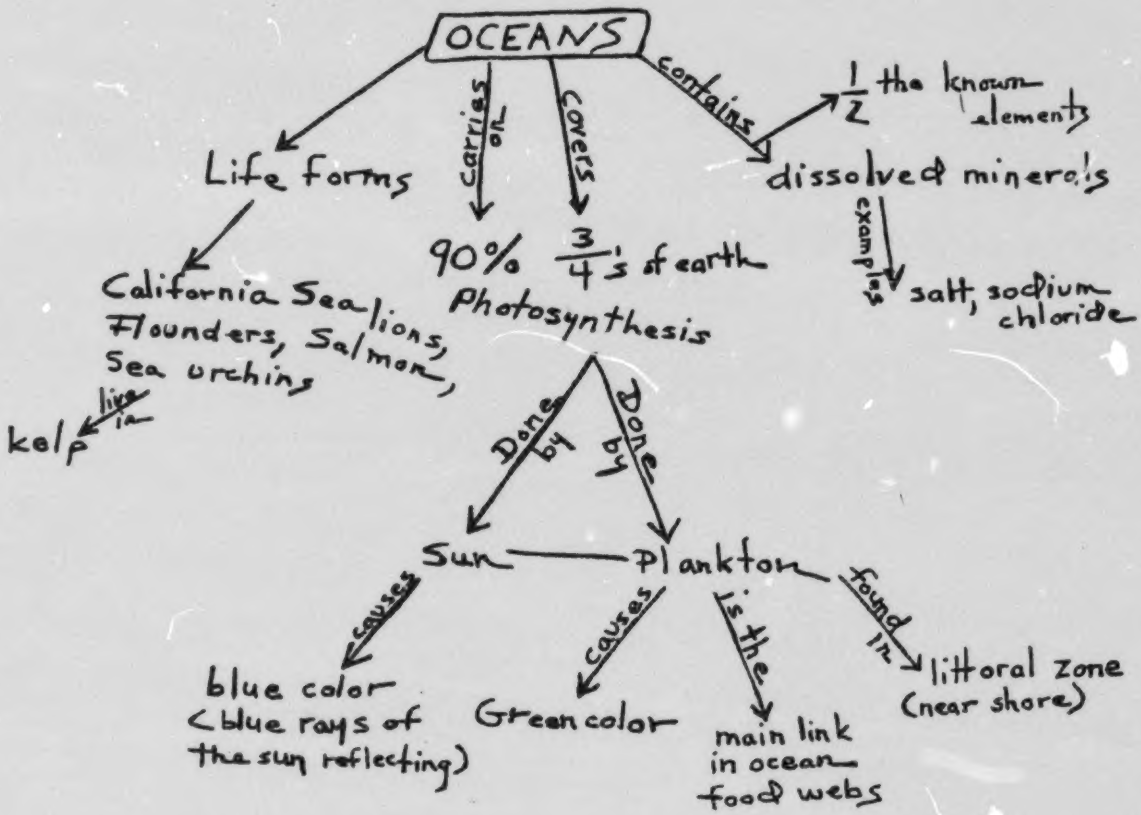
OCEANS
contains
1/2 the known elements
dissolved minerals
examples
salt, sodium chloride
carries on
90% Photosynthesis
covers
3/4's of earth
Life forms
California Sea lions, Flounders, Salmon, Sea urchins
live in
kelp
Done by
Done by
Sun
Plankton
causes
blue color (blue rays of the sun reflecting)
causes
Green color
is the
main link in ocean food webs
found in
littoral zone (near shore)

Figure 2: A Concept Map of the biome "Oceans," prepared by a group of four seventh grade students from a section of reading in their text.

To define a pen as a writing instrument is to relate the concept "pen" to the concepts of "writing" and "instrument." Figure 2 shows a concept map constructed by a group of seventh grade students from a textbook reading on world biomes. We will discuss the procedure for teaching and using concept maps in Section III of this handbook.

In summary, the "Learning How to Learn Program" is designed to be used in classrooms to help students understand the nature of knowledge and the nature of cognitive learning.

II. LEARNING

OVERVIEW OF THE AUSUBEL-NOVAK THEORY

ACTIVITIES IN MEANINGFUL LEARNING

SUMMARY

OVERVIEW OF THE AUSUBEL-NOVAK THEORY

Throughout the elementary school program, it is common for students to memorize definitions or procedural rules without relating the meanings of the words in the definitions or rules to ideas they already understand. In fact, students often come to believe that rote memorization of school information is the only way to learn. As teachers, we may want to reduce rote learning, but often find ourselves helpless to achieve more meaningful learning in the classroom. Two major reasons for this dilemma are: (1) the student is not aware that there is an alternative to rote learning, and (2) concepts that are to be learned are presented in such a way as to encourage rote memorization.

The intention of this section of the "Learning How to Learn Handbook" is to provide the student with an alternative to rote memorization by showing him/her that it is more efficient to learn in a meaningful way. Further, this section and the ones that follow will provide the teacher with information about how instruction can be organized to facilitate meaningful learning and discourage rote memorization.

The Ausubel-Novak learning theory attempts to provide a description of how learning takes place in the learner, how the learner processes new information, and how that information is stored. Already, two terms of the Ausubel-Novak theory have been introduced. The first is rote learning. Rote learning occurs when information that is learned is stored arbitrarily within the cognitive structure* of the individual. In other words, the new information or concept has no psychological connection to other concepts and their meanings. Activity #1 in this section is an example of information that is learned rotely. If quizzed on the meaning of the words (concepts) of the Pledge of Allegiance, how many students would be able to give adequate answers?

The opposite of rote learning is meaningful learning. Meaningful learning occurs when the learner is able to link new information to concepts and meanings that s/he already has in his/her cognitive structure.

*cognitive structure is the composite of stored knowledge representing the concepts, propositions, and other information learned by an individual.

In other words, new information to be learned is not taught arbitrarily, but always in relation to what the learner already knows.

In the following sections, learning activities are suggested that will help students understand the differences between rote and meaningful learning. Activities #2 and #3 illustrate the difference between rote learning and meaningful learning. List #1, on page II-4, requires that the student memorize the terms in a rote fashion. List #2, although the same instructions are given, has the concepts arranged in a more meaningful way. That is, they are already organized according to ice cream flavors, animals, furniture, and colors. While doing this activity, the teacher should find that the group of students with List #2 is able to learn the list of items more quickly than those students with List #1. Lists #3 and #4 on page II-5, demonstrate the distinction between rote learning and meaningful learning is not always a simple one. List #3 gives the names of a group of flowers; List #4 gives the botanical names for parts of a plant. Which one is more meaningful? Which is more rote?

Activities #3, #4, and #5 will demonstrate the use of prior experiences and knowledge to provide the organizing links that make new information more meaningful. Activity #4 does this by giving one group of students an organizing sentence which provides the meaningful link between the prior knowledge and the new information in the paragraph. Activity #5 introduces the idea of concept mapping as a means of organizing the information learned into a more meaningful fashion. And Activity #6 illustrates the idiosyncratic nature of the concepts that a learner possesses. Although each person stores information in an idiosyncratic way, there are enough regularities among the meanings of our stored concepts so that communication can occur.

In the last activity, the distinction between rote and meaningful learning is considered more directly. In this one, the learner is asked to identify those concepts that s/he considers meaningfully learned and those s/he considers rotely learned. The meanings of the concepts, indicated by the regularities we recognize for that concept and the specific events and objects as example of each concept, demonstrate the relative meaningfulness of these concepts to students.

It is hoped that through the examination of the concepts of rote learning and meaningful learning the student can recognize what is required to move toward meaningful learning and away from rote learning. Further, it is hoped that the teacher can begin to re-examine how information is presented to the learner, either in lessons or in textbooks. And that the strategies presented in the "Learning How to Learn Program" can facilitate this transition to the more meaningful, efficient teaching and learning of concepts.

ACTIVITIES IN MEANINGFUL LEARNING

ACTIVITY #1 - Rote Learning

Say the Pledge of Allegiance to the Flag. This is an example of something which is learned rotely. It is shared by everyone, and it must be said exactly as written or it is wrong.

Perhaps you may wish to write the Pledge of Allegiance on the board and circle key concepts, such as "allegiance" and "republic," and ask who knows what these concepts mean.

ACTIVITY #2 - Rote Learning and Meaningful Learning

If some information is going to be learned meaningfully, that information must be linked to existing concepts that the student already possesses. This can be shown in the following exercises. Give List #1 to half the class; List #2 to the other half. Give the following directions: "Here is a list of words. Everybody has the same words. You will be given thirty seconds to memorize the list that you have."

List #1

vanilla
elephant
desk
yellow
chocolate
red
table
camel
strawberry
green
horse
chair

List #2

vanilla
chocolate
strawberry

elephant
camel
horse

desk
chair
table

red
yellow
green

Figure 3. Lists of Organized and Unorganized Words.

After the thirty seconds, have the students list as many words as they can remember. Tally the number of remembered words for each student using List #1 and for those with List #2. The number of words each student remembers is a record of this learning-recall event. Determine the average for each group. The average number of words recalled (usually about 6+ for the group with List #1, and 8+ for the group with List #2) is a transformation of the original records, and serves to illustrate how the learning principles guide the inquiry. (See IV-2 through IV-12 for further discussion.)

Discuss with your students the idea of organization and meaningfulness of the material. List #2 already had the words organized into a pattern of ice cream flavors, animals, pieces of furniture, and colors. List #1 did not have that organization, or at least, the organization may not have been apparent after only thirty seconds. List #2 is meaningful for the student who realizes that the items are categorized.

You may want to try the next two lists to stress the point of meaningfulness for the students. Each list deals with plants, but List #4 may present some difficulties to the students since the terms are unfamiliar. It will be very difficult for the students to learn the list in the last column. This is an example of arbitrary learning or rote learning.

List #3	List #4
petunia	tracheid
gardinia	sclerenchyma
marigold	xylem
zinnia	cambium
goldenrod	epidermis
sunflower	mesophyll
maple	parenchyma
sycamore	pallisade
cottonwood	stomata
walnut	aperture

Figure 4. Lists of Familiar and Unfamiliar Botanical Names.

ACTIVITY #3 - Organizing for Meaningful Learning

How we interpret and relate to a problem often depends on our past experiences. These experiences help us to sort out our new information. On this page and the next are two paragraphs,* identical except for the first sentence. Divide the class once again into two groups, and give them the following directions. "You will be given a paragraph to read. After you have read it, you will be asked questions about the contents of the paragraph, and what the paragraph is discussing."

> This paragraph is about washing clothes. It is actually quite simple. First, you arrange things into different groups depending on their makeup. Of course, one pile may be enough depending on how much there is to do. If you have to go somewhere else due to a lack of equipment, that is the next step, otherwise you are pretty well set. It is important not to overdo any particular part of the job. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but trouble from doing too many can easily arise. A mistake can be expensive as well. Working the equipment should be self-explanatory, and we need not dwell on it here. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to see an end to the necessity for this task in the immediate future, but then one can never tell.

Figure 6A. Washing Clothes Passage with Organizing Sentence.

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*from R.E. Meyer. (1977) THINKING AND PROBLEM SOLVING: AN INTRODUCTION TO HUMAN COGNITION AND LEARNING. Glenville, IL: Scott, Foresman & Company.

It is actually quite simple. First, you arrange things into different groups depending on their makeup. Of course, one pile may be enough depending on how much there is to do. If you have to go somewhere else due to a lack of equipment, that is the next step, otherwise you are pretty well set. It is important not to overdo any particular part of the job. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but trouble from doing too many can easily arise. A mistake can be expensive as well. Working the equipment should be self-explanatory, and we need not dwell on it here. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to see an end to the necessity for this task in the immediate future, but then one can never tell.

Figure 6B. Washing Clothes Passage without Organizing Sentence.

Questions for the Class:

Who understand the story? Indicate by raising your hand?
Who does not understand the story?
For those who do understand the story, read the first sentence of your paragraph.

Students who had paragraph 6A will generally say they understand the story, and those with paragraph 6B may make some "wild guess" as to what it was all about. This exercise serves to illustrate that we can sometime aid the process of meaningful learning by statements that help to "organize" ideas by linking these ideas to what is already familiar. Meaningful learning is aided by procedures which help students tie new information to knowledge they already understand.

ACTIVITY #4 - Organizing by Means of a Concept Map

The purpose of this activity is to illustrate a valuable strategy for organizing material to be meaningfully learned. It introduces the idea of concept mapping of verbal material.

Again, divide up the class into two groups. Group #1 will receive the paragraph reading; Group #2 will receive the concept map on the next page. Give the students the following directions: "You will be given a sheet of paper with some information on it. The two groups have the same information, but in different forms. Study the piece of paper for four minutes. After that time, you will be given a quiz about the information on the papers."

> Everyone is familiar with metals. Metals that occur naturally are called pure metals. Some pure metals like gold, silver, and platinum are considered precious metals because they are rare. Copper, lead, iron, and aluminum, on the other hand, are considered common because they are more abundant. People have learned to combine pure metals and other substances to create new metals, called alloys. Steel, brass, and bronze are alloys. We see metals every day in cars and buildings (alloys mostly), in jewelry (rare metals) and in plumbing pipes and cooking foil (common metals).

Figure 7A. Metals Paragraph.

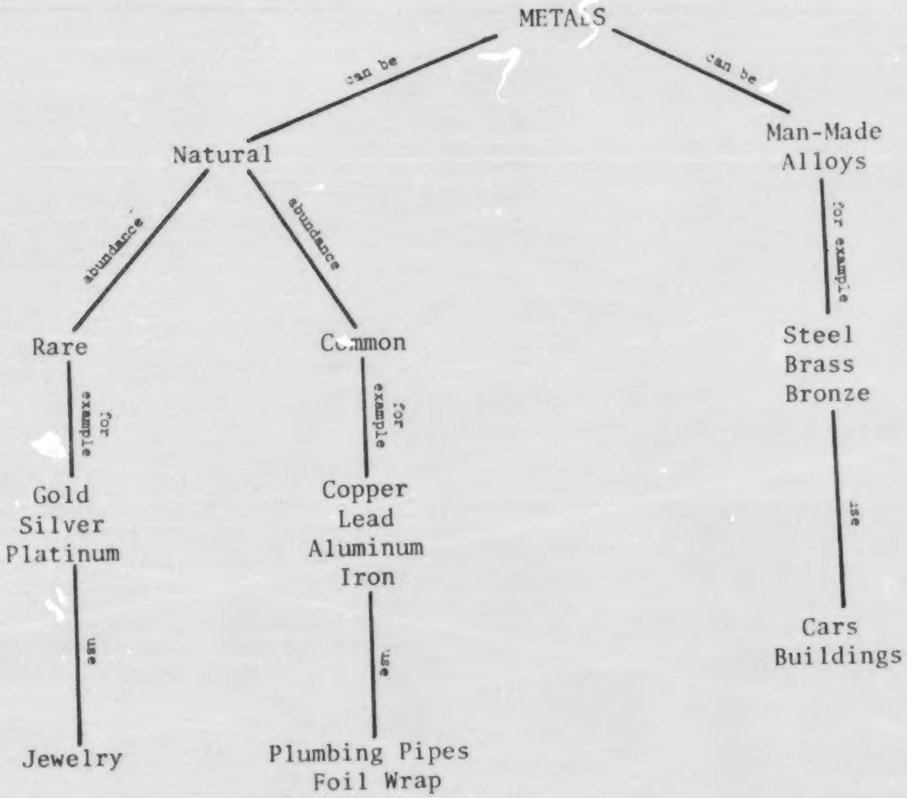

METALS
can be
can be
Natural
Man-Made
Alloys
abundance
abundance
for example
Rare
Common
Steel
Brass
Bronze
for example
for example
Gold
Silver
Platinum
Copper
Lead
Aluminum
Iron
use
use
use
Cars
Buildings
Jewelry
Plumbing Pipes
Foil Wrap

Figure 7B. Metals Concept Map.

Activity #4 Questions for Groups #1 (Paragraph readers) and #2 (Concept Map readers).

1. What is the best word label for the subject of this information?
2. Write the difference between pure metals and alloys.
3. Why are gold and silver called precious metals?
4. List two common pure metals.
5. Choose two from this list that are alloys.

   Platinum
   Bronze
   Copper
   Steel
   Aluminum

6. Metals used in cars and building are mostly ________.
7. Precious metals are mainly used for ________.

ACTIVITY #5 - Concepts and Stored Meanings

This activity illustrates that meanings are stored and that these meanings are idiosyncratic. That is, not everyone has the same meanings stored for each term. In asking the students to share their definitions of each word, they can come to realize that definitions do not match exactly since it is the meaning that is stored, and not the word. Also, there are aspects of the definitions that students do hold in common. These common features of the definitions could represent the regularities of the concept word. (See Activity #6.)

Ask the students to write their definition for each of the following:

ANIMAL FOOD AIR

Have the students share their definitions.

Questions for the Class:

Where did the information (given in the definitions) come from?

Why doesn't everybody's definitions match exactly? (Because it is their meanings which are stored.)

What are the aspects of the definitions that are held in common? (These could be the regularities of the concept.)

This activity also seems to illustrate that concepts vary in the extent of meaning they have for any one person. Concepts are more meaningful when they are related to larger sets of other concepts through meaningful propositions, such as "animals include vertebrates and invertebrates." The next activity seeks to help define concepts and to emphasize that each concept symbol or sign represents a specific regularity in objects and events. It is not always easy to describe the regularity represented by a concept label, even when we are very familiar with the concept, as in the examples given above.

ACTIVITY #6 - The Rote-Meaningful Continuum

The extent to which anyone can learn something meaningfully depends upon, (1) the potential meaning of the material, (2) the degree of development of related concepts by the individual, and (3) the effort to relate the new material to what the learner already knows. These three criteria can be illustrated in this activity. The potential meaningfulness of concepts relates the our ability to see the regularities that those concepts possess, and our ability to point to objects and events which are examples of those concepts. Give students the following directions: "Here is a line which represents a range from meaningful learning to rote learning. Choose eight to ten concepts and arrange them according to how meaningful they are to you. Try to use some concepts that represent regularities in objects and some that represent regularities in events. Those which are most rote should have the least meaning; those which are meaningful should have the most meaning. Indicate what the regularities are for each of the concepts and identify the objects or events of that designated regularity."

MEANINGFUL ↑	Concept	Regularity	Event/Object
	love	concern, feeling for others	acts of caring and feeling
examples	wind	moving air	air in motion
	fruit	usually edible, soft, food from plants	apples, bananas, tomatoes
ROTE ↓	phone number	assigned number	specific number, e.g. 555-1000

Figure 8. The Rote-Meaningful Continuum, showing examples of concepts, their regularities and the events or objects.

SUMMARY

After these activities are completed, it would be helpful for the teacher to summarize what information has been obtained. The use of the summary is to provide the student with some principles about learning, specifically about how s/he learns in school, and to provide the teacher with some operating principles that can guide the construction of lessons and units in a meaningful fashion.

-Rote learning occurs when new information is stored arbitrarily. That is, the information is not linked to existing concepts that the learner already has.

-Meaningful learning occurs when new information is acquired and linked to existing concepts that the learner already possesses.

-Existing concepts that the learner possesses act as organizing concepts that provide "anchorage" for new information and facilitate meaningful learning.

-The relationships among the concepts in individuals are idiosyncratic. That is, the concept meanings are unique for each individual.

-However, the meanings stored by individuals should have enough regularities to allow communication.

-Concepts gain in meaning when they can be used in more and more meaningful propositions.

III. CONCEPT MAPPING

FEATURES OF A CONCEPT MAP

CONSTRUCTION OF A CONCEPT MAP

SUGGESTIONS FOR TEACHING CONCEPT MAPPING

FEATURES OF A CONCEPT MAP:

Concept mapping is a means by which concepts and the organization of subject matter can be represented. Both students and teachers find that the use of concept mapping helps "see the subject matter more clearly, and learn that subject matter more meaningfully." Two concept maps have already been presented in this handbook; the metals concept map, Figure 7B, page II-9, and a more complex example on the ocean biome, Figure 2, page I-3. Both of these demonstrate the common features of all concept maps, and it is suggested that you refer back to them during the following description.

A concept map is a two-dimensional representation of a discipline or a part of a discipline. (Stewart, et al, 1979) And it is this feature that allows for the representation of the propositional (principle) relations among the concepts. This is a much different perspective than traditional note-taking which is one-dimensional and illustrates no relationships among the concepts. The concept map not only identifies the major points of interest (concepts), but also illustrates the relationships among the concepts in much the same way the links among cities on a roadmap are illustrated by highways and other roads.

Another feature of a concept map deals with its representation of the relationships among the concepts. Not all concepts have equal weight. That is, some are more inclusive than others. For instance, the concept of "natural selection" is more inclusive than any of the propositions that identify that theory. Thus we can see that every concept map should have at its top the most general, most inclusive concept, and progress down through until the least inclusive, more specific concepts or examples are illustrated at the bottom of the map. The ocean biome concept map (Figure 2, page I-3) illustrates "Salt" and "Sodium Chloride" as examples of "Dissolved Minerals." The "littoral zone" further down the map could have the "Long Island shore" as an example.

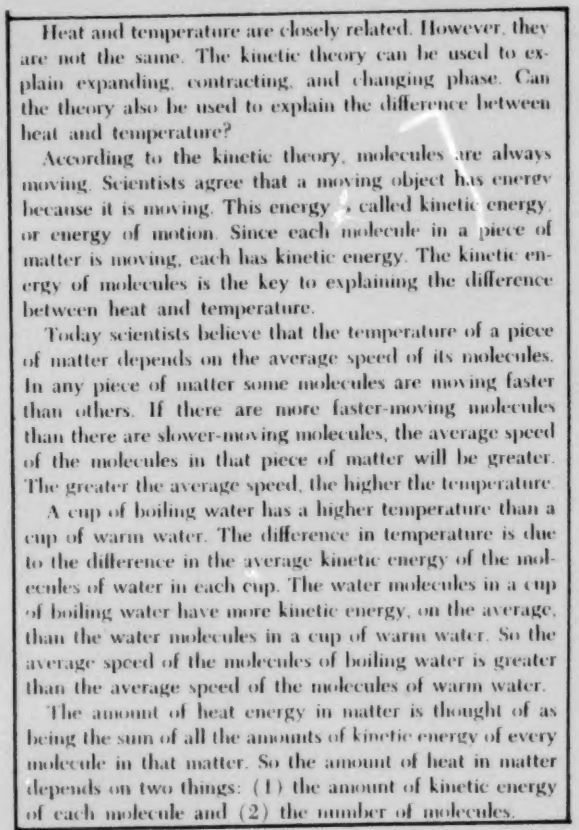
The next feature of a concept map is that of hierarchy. When two or more concepts are illustrated under a more inclusive concept, a hierarchy is produced on the concept map. Again from our ocean biome example, the concepts of "sun" and "plankton" are more specific concepts for the process of "photosynthesis," and illustrates a hierarchy of the food production in the oceans. In the metals concept map "pure" metals are classified into "rare" and "common" metals. By contrast, the examples of "copper," "lead," "aluminum," and "iron" show a linear relation to the concept of "common" metals, and thus no hierarchy is illustrated.

In addition to the features of being two-dimensional, showing a pattern of general to specific, and indicating a hierarchy, concept maps have other features. These features are more elaborate and discriminating. For a description of these other features, see Section V, the Assessment of Student-Constructed Concept Maps, page V-4.

CONSTRUCTION OF A CONCEPT MAP

To illustrate the points made more clearly, it will be helpful to construct a concept map step by step so that you can see the features and procedures necessary for a map's development. Although general rules are established for map construction, the teacher is advised that these rules will have to be modified and adapted to the particular teaching situation of your classroom.

The concept map that will be constructed is based on the reading to the right, and is taken from a junior high science text.



Heat and temperature are closely related. However, they are not the same. The kinetic theory can be used to explain expanding, contracting, and changing phase. Can the theory also be used to explain the difference between heat and temperature?

According to the kinetic theory, molecules are always moving. Scientists agree that a moving object has energy because it is moving. This energy is called kinetic energy, or energy of motion. Since each molecule in a piece of matter is moving, each has kinetic energy. The kinetic energy of molecules is the key to explaining the difference between heat and temperature.

Today scientists believe that the temperature of a piece of matter depends on the average speed of its molecules. In any piece of matter some molecules are moving faster than others. If there are more faster-moving molecules than there are slower-moving molecules, the average speed of the molecules in that piece of matter will be greater. The greater the average speed, the higher the temperature.

A cup of boiling water has a higher temperature than a cup of warm water. The difference in temperature is due to the difference in the average kinetic energy of the molecules of water in each cup. The water molecules in a cup of boiling water have more kinetic energy, on the average, than the water molecules in a cup of warm water. So the average speed of the molecules of boiling water is greater than the average speed of the molecules of warm water.

The amount of heat energy in matter is thought of as being the sum of all the amounts of kinetic energy of every molecule in that matter. So the amount of heat in matter depends on two things: (1) the amount of kinetic energy of each molecule and (2) the number of molecules.

Figure 8: Reading from Blecha, Fisk, and Holly. (1976). EXPLORING MATTER AND ENERGY, PAGE 148.

1. Select a reading from a text that is not too long. At least at first, the reading should be short

so that the concept map does not become too large and contain too many concepts.

2. Identify the major relevant concepts, that is, science concepts, by either underlining them in the paragraph or by writing them individually on pieces of paper or small cards. The relevant concepts for the reading are shown in Figure 9 below.

KINETIC THEORY, HEAT, TEMPERATURE, EXPANSION, CONTRACTION, CHANGE OF PHASE, MOLECULE, MOVING, ENERGY, KINETIC ENERGY, MATTER, AVERAGE SPEED, BOILING WATER, WARM WATER, NUMBER OF MOLECULES, LESS, GREATER.

Figure 9: Relevant Concepts from the Reading on Heat and Temperature.

3. While the list above generally shows how the concepts appear in the reading, this may not necessarily represent how the concepts are related to each other in the discipline. The next step then is to order or rank the concepts from the most inclusive (general) to the least inclusive (specific). Each reading, or section of text chapter, or even the entire chapter should have some concept which, because of its inclusiveness, is selected as the most general, or inclusive, of all the concepts presented. Sometimes, though, the inclusiveness depends upon the learner who uses his/her stored meanings to designate the most general concept. The examples will form the bottom of the concept map. What lies between the most inclusive concept and the examples at the bottom will be the intermediate concepts. Although these are not arbitrarily assigned to positions on the concept map, their positions on the map are less crucial to the overall function of the map. On the next page is a chart showing the range of inclusiveness of the concepts presented in the reading on previous page.

most inclusive	↑	KINETIC THEORY
		EXPANSION, CONTRACTION, CHANGE OF PHASE, HEAT, TEMPERATURE, MATTER
		AVERAGE SPEED, MOLECULES, KINETIC ENERGY, MOVING
least inclusive (examples)		LESS, GREATER
		WARM WATER, BOILING WATER

Figure 10: Chart of Ranking of Concepts from the Reading on Heat and Temperature

4. Now begin to arrange the concepts on a table or piece of paper, starting with the most inclusive at the top, followed by the next most inclusive.
5. This same procedure continues until all the concepts have been laid out. The connections among the concepts must now be established. Lines are used to connect the concepts and a statement is written on the line that indicates what the relationship is between any two concepts. The completed concept map for the reading on heat and temperature is shown on the next page in Figure 11.
6. The teacher is now encouraged to examine some of the teaching materials they have and to prepare concept maps for short sections of that material. Practice is the key to good concept mapping: proficiency will come as the map constructor makes a number of attempts.

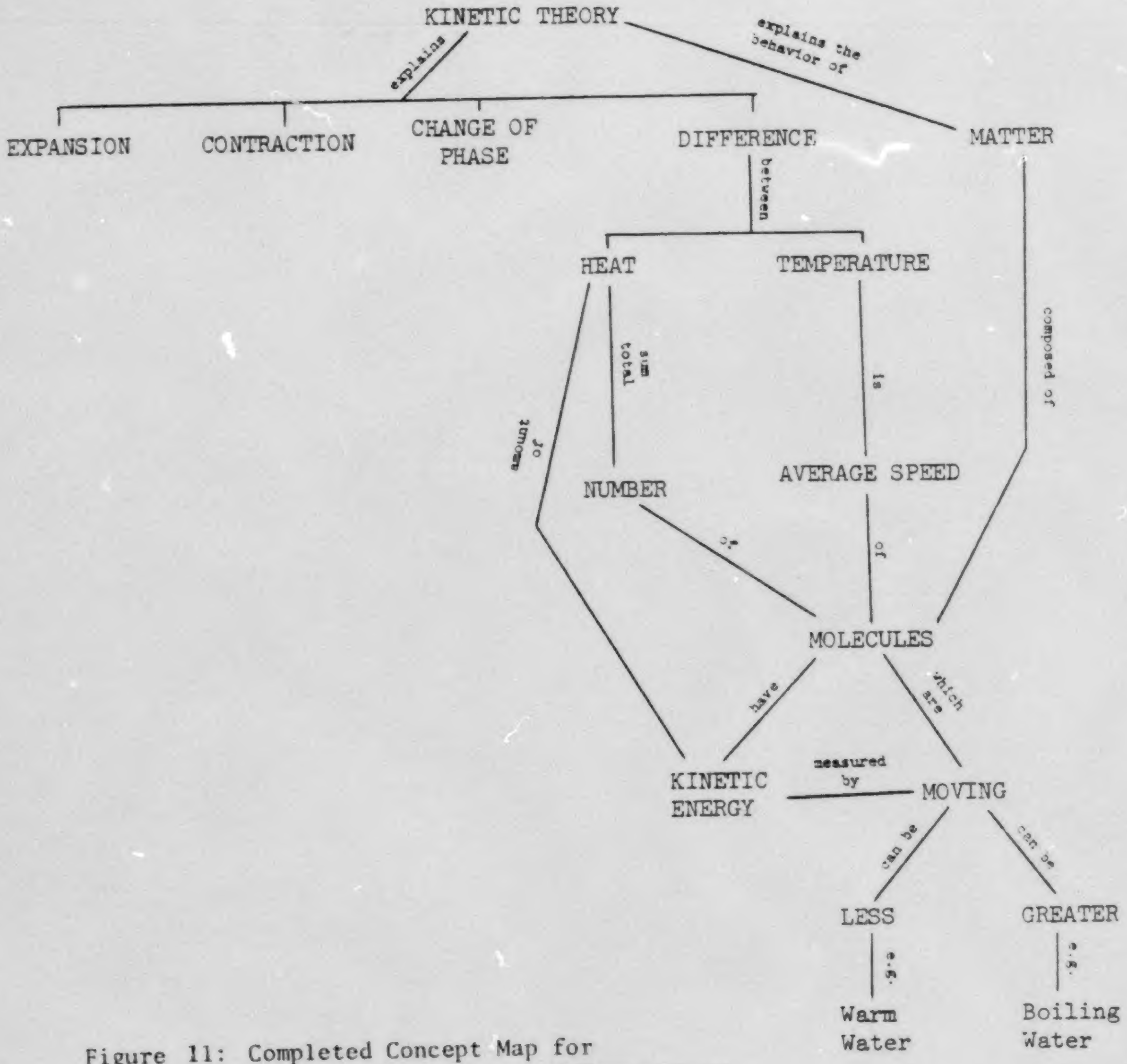

KINETIC THEORY
explains
explains the behavior of
EXPANSION
CONTRACTION
CHANGE OF PHASE
DIFFERENCE
MATTER
between
HEAT
TEMPERATURE
amount of
sum total
is
composed of
NUMBER
AVERAGE SPEED
of
of
MOLECULES
have
which are
KINETIC ENERGY
measured by
MOVING
can be
can be
LESS
GREATER
e.g.
e.g.
Warm Water
Boiling Water

Figure 11: Completed Concept Map for the Reading on Heat and Temperature

There are some elements to a concept map that are not mentioned in the rules for their construction. These are given to facilitate the development of concept maps by both the teacher and the student.

1. A concept map does *not* have to be symmetrical. The concept map on page III-5 is lop-sided to the side of "Heat" and "Temperature." This should be of little concern. (You will notice, however, that if the concepts of "Expansion," "Contraction," and "Change of Phase" were developed in the same reading, that other side would have been developed more completely.)
2. Remember that a concept map is *visually efficient*. That is, it is a shortcut way of representing the concepts of the discipline. This should remind us that, as we first develop concept maps, we find that a final map comes only after a few tries. These attempts represent an effort to show the details of concepts and their relationships in the most efficient and consistent way.
3. As you examine the concept map on page III-5 more closely, you may realize that some of the concepts are not in the same form as they were in the reading. For instance, "Expansion" and "Contraction" were changed from "Expanding" and "Contracting." Generally, it has been found that changing the verb concepts to noun concepts facilitates the map's construction without losing any of the intended meaning.
4. It is sometimes advisable to add certain concepts, even though they are not "relevant" science concepts. Their purposes are to clarify the intention of the map, and more faithfully represent the form of the reading. The concept "Difference" was added for just these reasons.
5. Finally, it must be remembered that there are no perfect or correct concept maps, only maps that come closer to the meanings of the concepts for the map maker and others who read them.

SUGGESTIONS FOR TEACHING CONCEPT MAPPING:

In the last part of this section on concept mapping, suggestions for teaching this technique to students is discussed. The pacing of the introduction of concept mapping depends upon the local conditions in the school, the level of the student, and the difficulty of the subject matter.

1. When concept mapping is introduced, it is advised that the teacher make up the map prior to coming to class and hand out copies to the students. Let the students study the map along with their reading. This will give them an idea of what a concept map is, how it is structured, and how it can be used.
2. When the students are ready to attempt a map construction on their own, choose a reading which is particularly short and that contains concepts that are familiar to the students already.
3. Instruct the students to identify the major concepts in the reading, rank them in order of importance, and construct the map from the information they have. (It might be helpful and interesting for the students to use small pieces of paper or "1x3" cards to write the concepts on. Students, in our studies, have said that making concept maps is like puzzle fitting, and perhaps the teacher should approach the task from that standpoint.)
4. The teacher should expect that there can be reasonable differences among concept maps that the students develop. Not all the concepts will be identified, some will not follow the "general to specific" rule, while others may have difficulty identifying the most inclusive concept. As the students become more familiar with concept maps and their construction, these difficulties usually disappear. Students can usually produce very adequate concept after only a period of two to three weeks of exposure to this technique.

5. You may want to have students develop a concept map with you on the chalkboard or the overhead projector.
6. Sometimes groups of students can work together and construct a concept map of a section of text material. The ocean biome concept map on page I-3 is an example of a cooperative effort by four seventh grade students.
7. As the students become more proficient with the construction of concept maps, the teacher should begin to examine closely the line connections among the concepts on the map. Because these lines represent the relationships among the concepts, it is important to assess the students' understanding of these relationships. Two forms of criteria have been designed to assess concept maps done by students. One form has what can be described as a large "field of view" which attempts to give an overall picture of how the students are progressing in their ability to make concept maps. The second form has a small "field of view" and magnifies some of the features of concept maps by establishing more stringent criteria for the map's assessment. Refer to Section V, under "Assessment of Student-Constructed Concept Maps," for these techniques.

Ultimately, the objective is to have students coordinate what they have learned about concept mapping and the Knowledge "V" (discussed in more detail in the next section). Essentially, a concept map can represent the left-hand, conceptual, side of the "V" and already you may have noticed the correspondence between the terms for concept mapping and some of the terms on the left-hand side of the "V".

In the next section, the terms of the "V" are discussed, examples are given, and suggestions for introducing and teaching the "V" to students are provided.

IV. THE KNOWLEDGE "V"

INTRODUCTION TO THE KNOWLEDGE "V"

BACKGROUND INFORMATION AND DEFINITIONS OF TERMS AROUND THE "V"

USE OF THE "V" AS A PRE-TEACHING, TEACHING, AND LEARNING TOOL

SUGGESTIONS FOR INTRODUCING THE KNOWLEDGE "V"

INTEGRATION OF THE "V" AND CONCEPT MAPPING

INTRODUCTION TO THE KNOWLEDGE "V"

The nature and organization of cognitive structure not only plays a major part in our individual learning, but also forms the basis of the collective knowledge in the sciences (as well as other disciplines). The nature of knowledge and the analysis of knowledge can be taught through the use of Gowin's Knowledge "V". Briefly, Gowin defines two types of concerns that are used in conjunction with the intent of reaching or arriving at some knowledge claim. They are the conceptual and methodological activities. The left-hand, conceptual, side of the "V" indicates the appropriate questions to ask, and what theories, principles, and concepts bear on that question. This conceptual side is balanced with a methodological side which identifies what has been observed, gathered, and manipulated in the laboratory so that records and data are accumulated to substantiate the knowledge claim. What binds these two activities together are the objects and events that occupy the bottom of the "V".

Nine terms are associated with the "V". In the following pages, these terms will be defined, and examples from actual laboratory exercises will be given. The skeleton form of the "V" and its accompanying terms are given below.

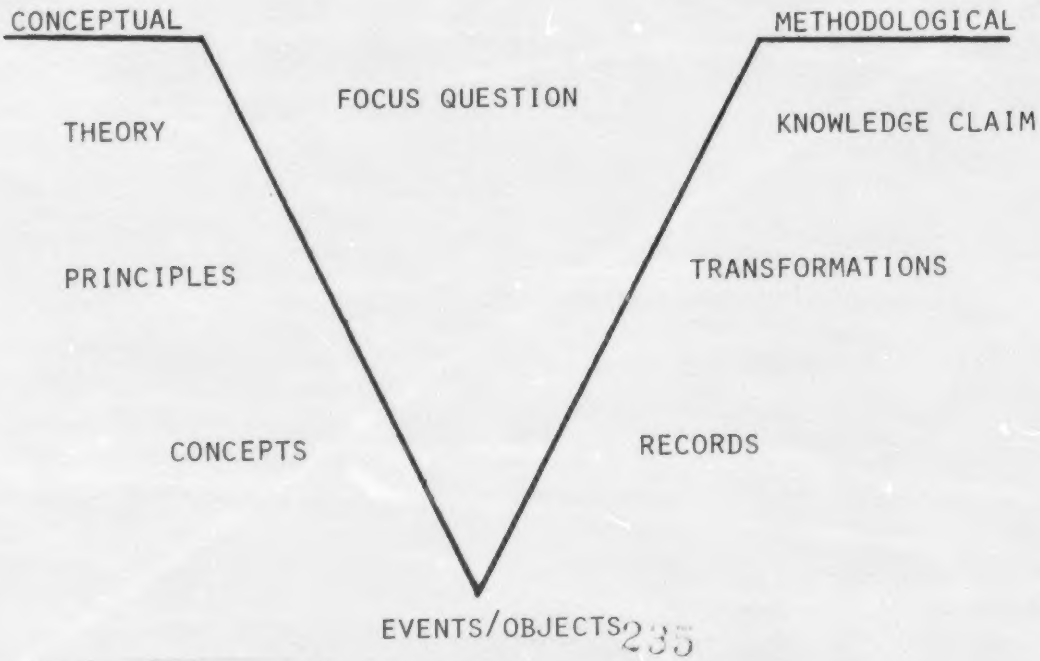
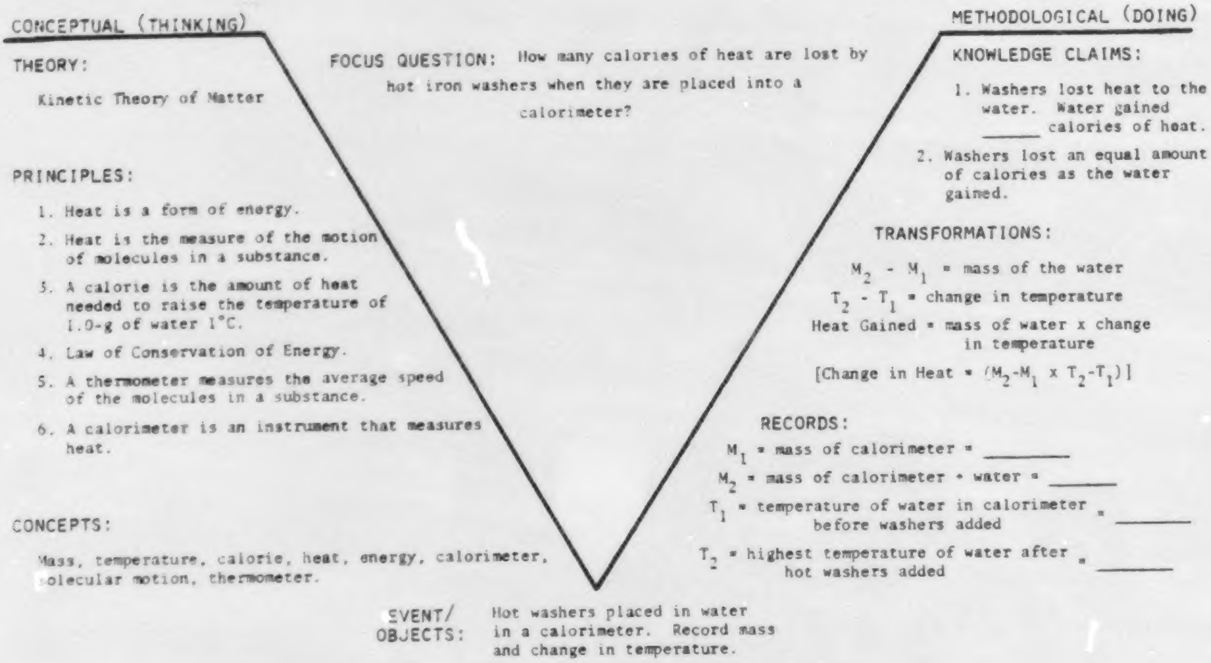


Figure 12: Gowin's Knowledge "V"

BACKGROUND INFORMATION AND DEFINITIONS OF TERMS AROUND THE "V"

The introduction of the "V" into the classroom requires that the teacher modify some of the definitions that are normally used. Although there is a great deal of commonality from the previous definitions associated with the so-called "scientific method" and the "V", some clarification of these terms is necessary. The following is written to accomplish the task of acquainting the teacher with the terms and definitions around the "V" and to facilitate the smooth introduction of the "V" as a teaching and learning strategy in the classroom. Two laboratory exercises have also been included, and will serve as reference points as the definitions are discussed. The first example is a laboratory exercise that was taken from a published laboratory handbook designed for a junior high physical science course. The lab exercise was laid on the "V" for analysis by the class. It is taken from the laboratory manual (pp. 27-28) which accompanies Blecha, et al. (1976) EXPLORING MATTER AND ENERGY.



CONCEPTUAL (THINKING)

THEORY:

Kinetic Theory of Matter

PRINCIPLES:

1. Heat is a form of energy.
2. Heat is the measure of the motion of molecules in a substance.
3. A calorie is the amount of heat needed to raise the temperature of 1.0-g of water 1°C.
4. Law of Conservation of Energy.
5. A thermometer measures the average speed of the molecules in a substance.
6. A calorimeter is an instrument that measures heat.

CONCEPTS:

Mass, temperature, calorie, heat, energy, calorimeter, molecular motion, thermometer.

FOCUS QUESTION: How many calories of heat are lost by hot iron washers when they are placed into a calorimeter?

METHODOLOGICAL (DOING)

KNOWLEDGE CLAIMS:

1. Washers lost heat to the water. Water gained ______ calories of heat.
2. Washers lost an equal amount of calories as the water gained.

TRANSFORMATIONS:

$M_2 - M_1$ = mass of the water

$T_2 - T_1$ = change in temperature

Heat Gained = mass of water x change in temperature

[Change in Heat = $(M_2 - M_1 \times T_2 - T_1)$]

RECORDS:

M_1 = mass of calorimeter = ________

M_2 = mass of calorimeter + water = ______

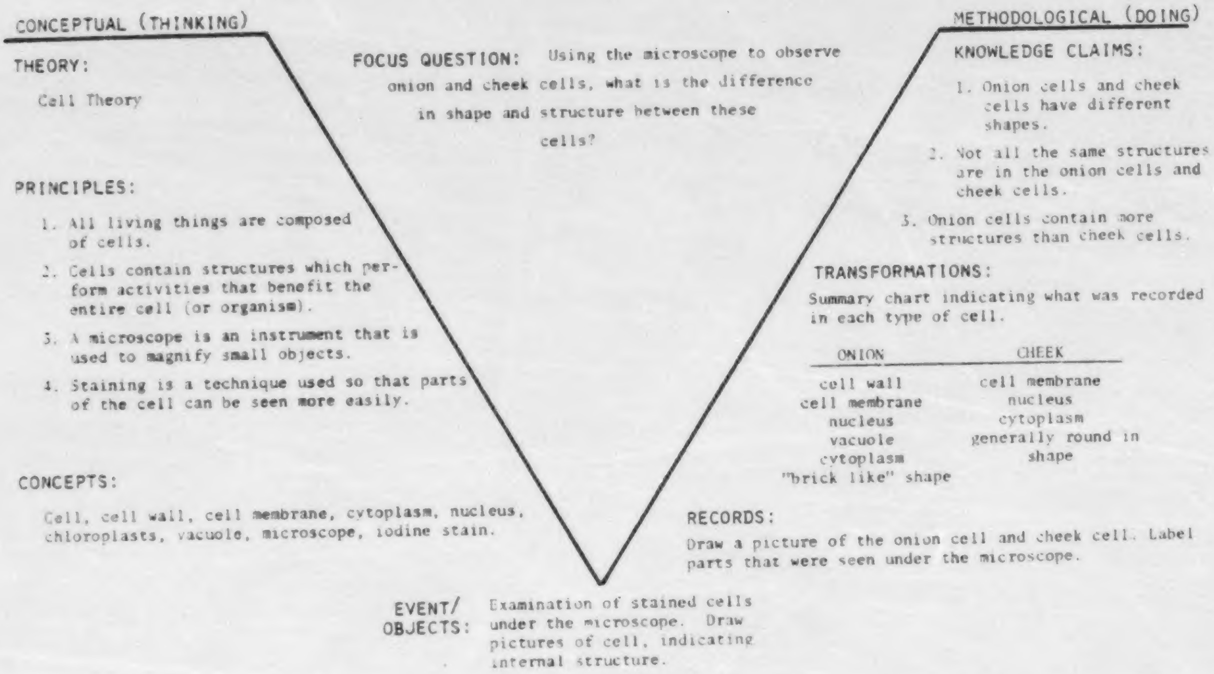
T_1 = temperature of water in calorimeter before washers added = ________

T_2 = highest temperature of water after hot washers added = ________

EVENT/ OBJECTS: Hot washers placed in water in a calorimeter. Record mass and change in temperature.

Figure 12. Sample "V" #1, produced from an exercise published in a laboratory manual.

The second example, for the purpose of contrast, is a laboratory exercise developed by a teacher for a seventh grade biological science course.



CONCEPTUAL (THINKING)

THEORY:

Cell Theory

PRINCIPLES:

1. All living things are composed of cells.
2. Cells contain structures which perform activities that benefit the entire cell (or organism).
3. A microscope is an instrument that is used to magnify small objects.
4. Staining is a technique used so that parts of the cell can be seen more easily.

CONCEPTS:

Cell, cell wall, cell membrane, cytoplasm, nucleus, chloroplasts, vacuole, microscope, iodine stain.

FOCUS QUESTION: Using the microscope to observe onion and cheek cells, what is the difference in shape and structure between these cells?

METHODOLOGICAL (DOING)

KNOWLEDGE CLAIMS:

1. Onion cells and cheek cells have different shapes.
2. Not all the same structures are in the onion cells and cheek cells.
3. Onion cells contain more structures than cheek cells.

TRANSFORMATIONS:

Summary chart indicating what was recorded in each type of cell.

ONION	CHEEK
cell wall	cell membrane
cell membrane	nucleus
nucleus	cytoplasm
vacuole	generally round in shape
cytoplasm	
"brick like" shape	

RECORDS:

Draw a picture of the onion cell and cheek cell. Label parts that were seen under the microscope.

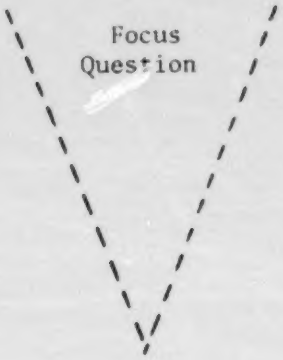
EVENT/ OBJECTS: Examination of stained cells under the microscope. Draw pictures of cell, indicating internal structure.

Figure 13. Sample "V" #2, produced from a "classic" junior high biological science laboratory exercise.

CONCEPTUAL/METHODOLOGICAL SIDES

In our work with junior high students, we have found it helpful to use these two terms in coordination with two other terms that the students are more familiar with. We can talk of the conceptual side as the thinking side, and the methodological side as the doing side. Whether the teacher wants to use the "five dollar" words or the more common terms, or both, is left as an individual choice.

FOCUS QUESTION



The promotion of conceptual change is fostered by the development of good questions. A good question is one that leads to an examination of objects and events, theory and concepts, so that new knowledge is constructed. Thus, a good focus question will arise from the examination of the concepts that a student has, will steer the methodology (right-hand side), and will eventually lead up through the knowledge claim. New knowledge claims enhance the meanings of the concepts, principles, and theories. As each knowledge claim is collected, it can lead to a refinement of the concepts used to form that knowledge claim. But what is the function of the focus question in all of this? The focus question indicates the kind of knowledge claim that will be made, what concepts and principles need to operate in the inquiry, and should suggest the major event that will be examined and recorded. In our example of the difference between onion and cheek cells, the focus question indicates clearly what concepts are being used (cell, difference, structure, shape, onion, and cheek), and the major event of that inquiry (looking at these cells with the microscope).

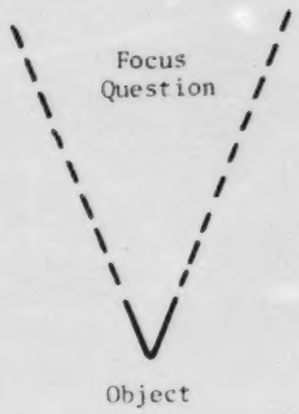
Of course, there are several kinds of questions that can be asked as a focus question. In some laboratory exercises, the questions only asks for a "what", for instance, "What is the difference in structure between onion cells and cheek cells?" In these cases, a simple identification of something is required. To ask, by contrast, "How is the structure of a cell related to its function?" requires a different operation. In this case, the question asks for some kind of description, not an identification.

Another kind of question that is sometimes asked in the laboratory exercise is a "why" question. The function of this kind of question is to focus on not an identification or a description but an explanation.

In this case, more than any other, a theory or some theory-bound principle must be used as a conceptual ingredient of the left-hand side. For instance, to ask, "Why are onion cells different than cheek cells?" or "Why do the hot washers give up heat to the water?" requires that we bring to the knowledge claim some explanation that is consistent with the theory that is identified on the upper left-hand side.

From this, we can summarize two functions of a good focus question. First, it focuses upon the concepts, principles, theory, and event that will be used in the construction of a knowledge claim. Secondly, it focuses upon the kind of knowledge claim that is to be made as we ask "what," "how," or "why."

OBJECT

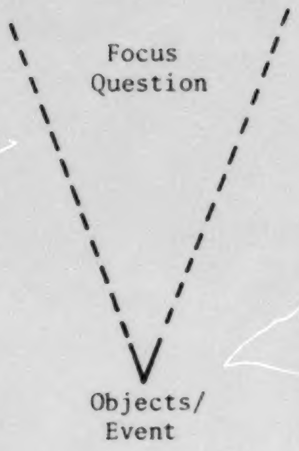


"Object" is one of the terms that is defined in a specific way when using the "V". Closely related to the "event," the objects are the things in the inquiry that allow the event to occur. In the examples given previously, the objects are the microscope, the cheek and onion cells, the calorimeter, the thermometer, and the water in the calorimeter.

We can also distinguish the key object of the inquiry from objects that are relevant, but less central to our focus question. The key objects of the cell experiment are the onion and cheek cells. The microscope is an object we need to perform our observations and to make our records.

We will return to a consideration of objects in two places further on in this handbook. When we consider the "event" of an inquiry, the objects will be distinguished from the "event." Also, when "concept" is discussed and defined, the distinction between "concept" and "object" will be examined.

EVENT



Even though we can talk about future "events," an occurrence is not an actual event until it happens or unfolds and we can take a record of it. Thus, we can conceptualize about and plan for our next birthday or an experiment to be done, but it is not an event until it begins to occur.

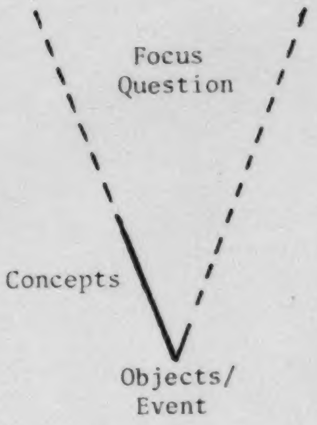
Events and objects are related in that objects are always involved in an event, and may even be the event itself (for instance, examining tree rings to determine the tree's age). Look back over the procedures from the laboratory exercises you have taught. What was going to occur? This is the major event. What was there so that the event could occur? These are generally the objects.

In the two laboratory exercises given as examples, the major event appears at the bottom of the "V" for each. In the lab involving onion and cheek cells, the major event is to look at stained mounts of these cells under the microscope; for the lab involving heat loss, the major event is the plunging of the hot washers into the calorimeter and recording the temperature change.

Events can either be made to happen (as in the two examples above), or the event may be occurring and we, at some time, come upon it. In either case, the event is the thing that we take a record of. This will be examined a little further on.

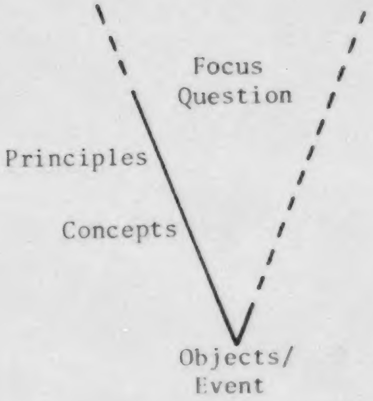
CONCEPTS

To understand the conceptual, left-hand side of the "V", it is imperative that the student and teacher understand what a concept is. Concepts refer to regularities in events or objects. For example, the concept of "cell" which is used in the experiment with onion and cheek cells has certain regularities that distinguishes it from other objects.



Not all onion cells are identical and not all types of cells look alike. But there are enough common features or regularities among all kinds of cells so that the concept "cell" can be used for a number of examples. In biology, the use of the term "typical cell" points up all the regularities that can be found generally in cells. In the experiment on heat loss, "calorimeter" is a concept used to designate the the instrument that will be used to measure the heat loss by the hot washers. For junior high school, the calorimeter used is a very simple one, being made of one styrofoam cup inside another, a top, and a thermometer. This is much different than the more sophisticated calorimeters used in formal science laboratories, but the simple calorimeter shares enough regularities with the sophisticated type to warrant that name of "calorimeter."

The final point to consider about concepts is how they are denoted. Language provides signs and symbols to designate the concepts. Simply, the sign or symbol of a concept is its name. Explore some of the kinds of symbols and signs that students use in science class and examine the regularities that those signs and symbols denote. You may also want to return to the consideration of meaning which was discussed in Activity #5 on page II-10.



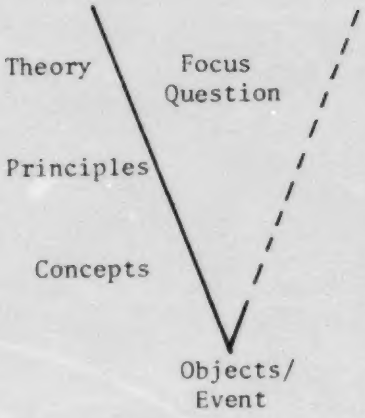
PRINCIPLES

Principles fit right above concepts on the left-hand side of the "V". A principle is a conceptual or methodological rule which guides the inquiry. Conceptual principles may find their source from knowledge claims of some previous research. There have been several examples identified in this handbook: Heat is a form of energy, Carbon dioxide is given off during fermentation; and,As the temperature increases, the rate of fermentation also increases. Each of these were constructed as a result of performing an empirical study.

Conceptual principles come also from theories. Theories contain principles, as propositions, which state the relationships among the concepts that the theory attempts to relate. An illustration of this relationship among concepts, principles, and theory will be discussed below in the section on "Theory."

There are also methodological principles which, as the name suggests, guide us primarily on the right-hand side of the "V". To state that a thermometer measures the average speed of molecules in a substance is a methodological principle derived from a theory guiding the use of that instrument. In the activities reported previously, try to pick out those principles that are methodological and those that are conceptual.

THEORY



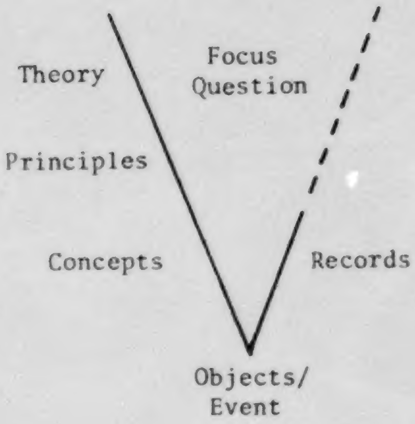
Theories are statements, developed by people, which attempt to explain and predict the interactions among concepts, events, and knowledge claims. Theories are labels, but these labels are not the theories themselves. The theory encompasses the relationships among the principles and concepts of that theory.

Perhaps the best way to illustrate how theories work is to provide an example of theory and its relationship to concepts and principles.

Expansion is a concept that denotes the regularity of a substance increasing in volume which is caused by some agent. The caloric theory of heat stated that heat, since it was a "fluid," infused into the substance causing the increase in volume. This illustrates the relationship among the theory (caloric theory), its propositions (heat is a fluid which moves from hotter objects to colder objects), and the concept (expansion). But the caloric theory could not explain all the phenomena associated with heat and heat transfer. Friction, for instance, did not easily fit into the caloric model of heat.

Another theory, the kinetic theory of matter, replaced the older theory, and stated different principles and different relationships among concepts that more adequately explained the phenomena of heat. The kinetic theory stated that heat was not a substance that moved from one body to another, but was the result of molecular motion within a substance. Thus, the heat energy in a substance was directly related to the molecular motion within that substance. The concept of expansion was explained in terms of the molecular motion. As more heat was added to a substance, the space between the molecules increased. This increase caused the increase of volume of the substance, that is, expansion.

In many instances in a junior high science class, the theory that stands behind the subject matter may not be evident to you or the students. Therefore, there will be times when you will not be able to fill in this part of the "V". However, it is important that students realize that some theory does indeed operate in the explanation of events and the prediction of new knowledge.

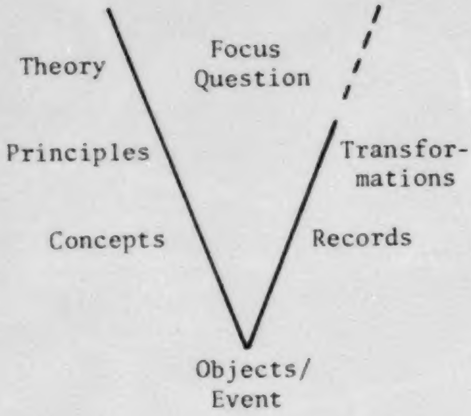


RECORDS

In order to be a record, we must take our sense perceptions of objects and events and produce them into a relatively permanent form which can be conveyed to others. The record may take the form of a written document, a photograph, or a tape recording. The records of the onion and cheek cells laboratory exercise are the diagrams that the students prepared. In the heat loss experiment, the students were instructed to record the temperature of the water in the calorimeter before and after the hot washers were plunged into the water. Other records about the mass of the water and calorimeter were also included.

It is important to realize that a record is made about the events and objects, not about concepts. We can take a record of a thermometer reading, or draw a cell, but we cannot make a record of the concepts of "temperature" or "cell."

TRANSFORMATIONS

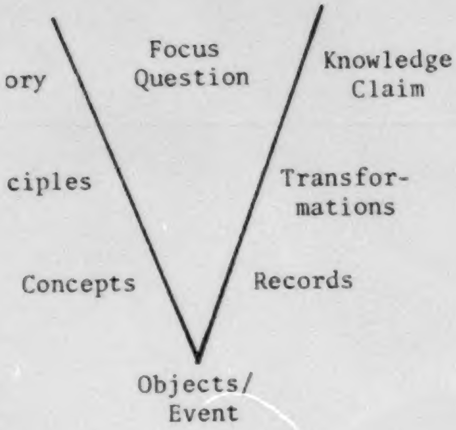


As you probably realize from the two examples given, making records of events and objects does not complete a scientific inquiry. In science, these records are often reorganized or rearranged into a more manageable form. When this is done, a transformation is performed. The type of knowledge claim determines the type of transformation needed.

The difference between records and transformations are often subtle. Generally, a record can be made of some sense perception, such as reading the temperature on a thermometer. A transformation requires some type of manipulation of several of these sense perceptions, such as computing the difference between the temperature before and after the hot washers are plunged into the water.

Transformations can take many forms, and may involve several steps. The most common in science and in science classes include graphs, simple differences, charts, statistics, or any comparison of two or more records. You might want to discuss this further with your students, indicating or soliciting from them examples of records and transformations found in the work that they have done. Examples could come from everyday experiences or from previous laboratory work.

KNOWLEDGE CLAIMS



There are two things that knowledge claims do. First, they are the answers to the focus questions that were asked at the start, and as such, provide information. Second, they can suggest new questions that can lead to new investigations.

Knowledge claims come from the inquiry that has lead to those knowledge claims. They must be consistent with the focus question, concepts, principles, objects, events, records, and transformations that preceded its construction. In our example of the onion and cheek cells, the cheek cells were claimed not to possess vacuoles. This was done because the observer, using the microscope, did not or could not detect vacuoles in those cheek cells. To state the claim that cheek cells, or animal cells in general, have vacuoles requires still another inquiry, using perhaps different representatives of animal cells or a stronger microscope. It is this activity -- realizing the limitation upon the knowledge claim made -- that spawns new questions and further investigations.

To familiarize yourself further with the structure and function of the knowledge "V", take a look at several of your own laboratory exercises and "lay them on the 'V'." It is only through this activity that you can fully comprehend the simplicity and power of this device both as a pre-teaching tool and a teaching tool.

USE OF THE "V" AS A PRE-TEACHING, TEACHING, AND LEARNING TOOL

The versatility of the knowledge "V" becomes evident as the range of possibilities for its use are examined. In our work with the "V" we have identified three different areas for its use: it is a pre-teaching, teaching, and learning tool.

As a pre-teaching tool, the "V" provides a strategy to analyze laboratory exercises prior to introducing them to the students. The teacher can take an existing experiment, and, using the "V", determine if that exercise is structured in such a way that it can facilitate meaningful learning. That is, the "V" allows the teacher to assess what concepts the students must know before beginning the experiment in order to make sense of the experience. Further, the "V" can be used as a device to construct individually-designed laboratory exercises for classes.

If it is kept in mind that the "V" is primarily a strategy for analysis, by asking certain questions, the teacher can analyze a laboratory work. In a manner of speaking, the teacher "unpacks" the work to examine its constituent parts. As the teacher unpacks the experiment, the "V" is used to answer a number of questions about the structure of the work. For these questions, you might want to examine the criteria, both general and specific, that are presented in "Assessment of Student-Constructed 'V's'" on pages V-12 through V-17 in this handbook.

As a teaching tool, the "V" fits nicely into what is traditionally known as the laboratory discussion. It can precede the actual laboratory experiment, where the left-hand, conceptual, side might be completed as a form of summary to re-cap what the student already knows about the task at hand. Indicating what kinds of records and transformations that will be made could facilitate the smooth movement of the lesson so that as little time as possible is expended with methodological problems.

The "V" also has versatility as a guide during the experiment. A partially filled "V" in front of the student during the actual running of the lab and record collection can give the student a short-hand approach for determining what to do next.

And finally, the "V" has worth as a summary technique after the experiment has been completed. As such, the student can see where his/her knowledge claim came from, what basis it had in the concepts that occupy the left-hand side, and the methodology on the right-hand side. As a summary device the "V" can be discussed as a whole class activity, where different groups of students compare results and knowledge claims, and attempt to discuss any discrepancies in the results.

Many teachers require written laboratory reports from the students. These reports usually summarize the experiment and also indicate certain inferences that follow from the work done in the experiment. The "V" can represent the short-hand form of that report, or the teacher can opt to have students prepare "V's" as the outline for an extended laboratory write-up.

Throughout this entire handbook, there have been two themes that have been developed about the "V" and its relation to education. First, than the "V" is a means of unpacking an inquiry, and is therefore a method of analysis. Second, the "V" provides a piece of knowledge about knowledge creation. If these two aspects of the "V" are kept in mind, then the use of the "V" as a learning tool becomes apparent. By providing a means of analysis, the "V" separates and identifies the major concepts and principles that are used to sort out and create the knowledge. This identification of what is required to make sense of the experiment provides the means by which the students can indicate what concepts they already know, how those concepts are related to each other, and how this linking of existing concepts can bring about new knowledge and new concepts. This is tightly consistent with the theory of learning developed in Sections I and II in this handbook. Thus, the "V", along with concept mapping, can provide strategies for meaningful learning.

However, the versatility of the "V" does not stop there. In essence, as we teach the "V", not only are we teaching for meaningful learning of concepts, but also teaching for the meaningful learning of how knowledge is made. While it is important for students to learn what the accumulated knowledge of science is, another type of learning is going on as the student uses these strategies -- that is, how science is constructed. Students learn what counts as a concept, how theories work in providing explanation, how concepts change over time, what are the intellectual commitments for record-making and transformations. and the limits of the constructed knowledge of the sciences. They come to realize that knowledge is the product of inquiry. And that inquiry comes about as a result of the interaction of the conceptual structure we possess and the methodologies we choose in the task of building that knowledge.

SUGGESTIONS FOR INTRODUCING THE KNOWLEDGE "V"

Given all this introductory material on the "V", it is also necessary to discuss some practical aspects of introducing the "V" into the classroom. These ideas are presented to facilitate the smooth introduction of the "V", and also provide options for you who will ultimately make the decision of what is best for your students.

1. Do not present the "V" and its accompanying terms out of context. That is, don't just teach the terms abstractly. The "V" should be introduced with respect to a laboratory exercise done, a demonstration completed, or some other relevant material.
2. Don't worry about the structure of the "V" immediately. As you and the class perform laboratory exercises, get them used to using the terms of the "V" -- "What is the record of this experiment?", "What is the focus question?", etc.
3. When the time is appropriate, and the students have a good understanding of the meanings of each of the terms, the structure of the "V" can be introduced. In some classes, you might want to complete some of the "V" for the students, having them finish the "V" as a result of having completed the laboratory exercise. In some other classes, you might want the students to complete the entire "V". That will be up to you.
4. As the students become more familiar with the "V", you might want them complete the left-hand side as a pre-lab and/or homework assignment.
5. Large poster boards of completed "V's" could be placed up around the classroom; a list of the theories and major principles used in class could be put on a bulletin board; also, concept maps could enhance the conceptual nature of the program. Not only will this give students handy reference sources, but will also reinforce the notion of conceptual teaching and learning.

INTEGRATION OF CONCEPT MAPPING AND THE KNOWLEDGE "V"

The final part of the knowledge "V" section relates the two strategies discussed in this handbook -- concept mapping and the "V". It has already been suggested that the left-hand, conceptual, side of the "V" can be represented by a concept map. The concept map has the purpose to conceptually guide initial and further inquiries through the formation of good focus questions.

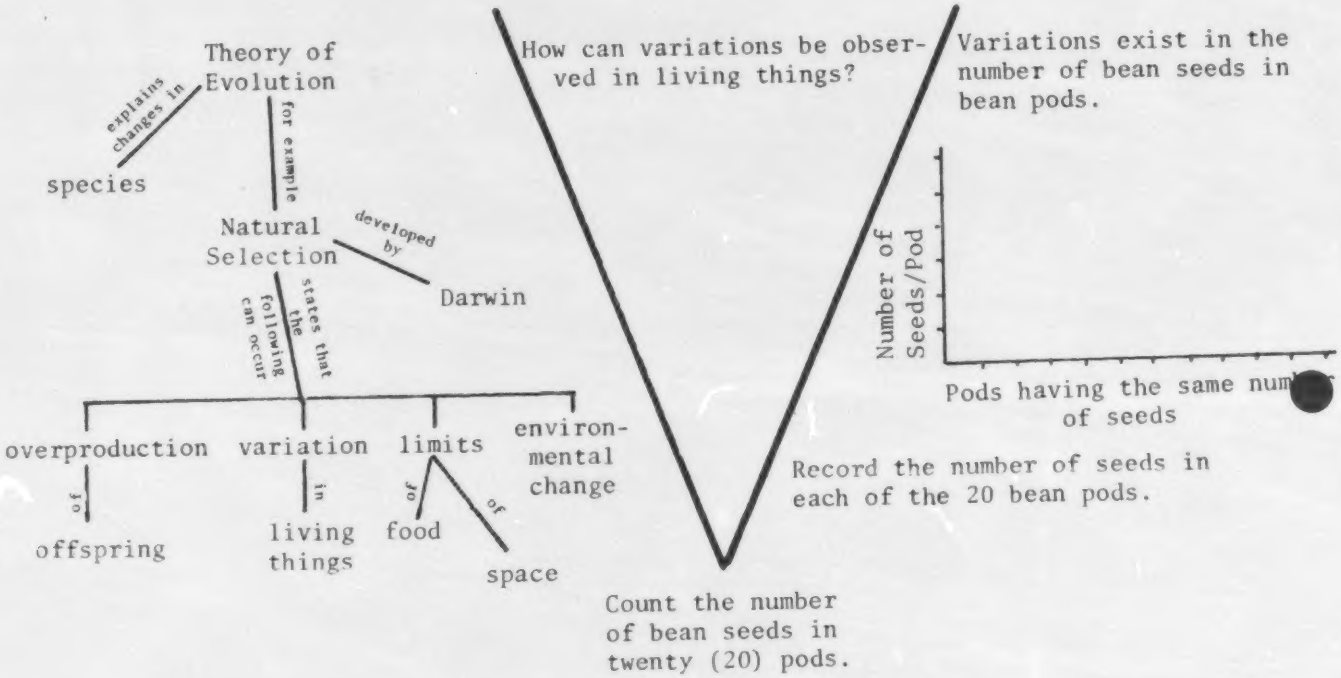

Theory of Evolution
explains changes in
species
for example
Natural Selection
developed by
Darwin
states that the following can occur
overproduction
of
offspring
variation
in
living things
limits
of
food
of
space
environmental change
How can variations be observed in living things?
Variations exist in the number of bean seeds in bean pods.
Number of Seeds/Pod
Pods having the same number of seeds
Record the number of seeds in each of the 20 bean pods.
Count the number of bean seeds in twenty (20) pods.

Figure 15: Integration of Concept Mapping and the Knowledge "V". Exercise is adapted from Kaskel, et al. (1977) Life Science: A Learning Strategy for the Laboratory, pp. 31-34.

Using the concept map and "V" above, the question could establish the relationship between two concepts that are represented horizontally on the map, e.g. between "limits of food" and "environmental change." Or the question could ask whether one concept is subordinate to another, such as, "What kinds of limits are imposed on organisms in an environment?" Or, as in the example above, whether a concept can be demonstrated. The focus question then sets the stage for the inquiry and provides the key for meaningful learning. As each focus question is answered, the conceptual structure of that part of the discipline grows for the student, and his/her knowledge becomes more complete and more complex.

In the next and final section, issues of evaluation are discussed. Given the psychological and nature of knowledge orientation of this approach, the evaluative instruments are somewhat different than what is usually used in science classes. Clear criteria for assessing students' ability to use concept mapping and the knowledge "V" has been devised to assist the teacher in determining how proficient the students are in each of these areas.

V. EVALUATION

ASSESSMENT OF STUDENT-CONSTRUCTED CONCEPT MAPS

EVALUATION OF KNOWLEDGE "V" - IDENTIFICATION, DEFINITIONS, AND EXAMPLES OF TERMS

ASSESSMENT OF STUDENT-CONSTRUCTED "V'S"

USING THE "V" IN SEQUENCE

INTEGRATION OF THE "V" AND CONCEPT MAPPING

CONCEPTUAL QUESTIONS: USE OF THE "V" AND CONCEPT MAPPING

Materials for evaluating concept maps and "V's" have been devised that are consistent with the information and background given in this handbook. Although these materials have been divided into various parts in this section, they actually work together to give the teacher a broad spectrum of ways of seeing how well students are performing with the various strategies.

Before each evaluation method is given, a description of what that method is intended to do is discussed. These objectives should be kept in mind as the teacher both reads the methods and uses them in the classroom.

ASSESSMENT OF STUDENT-CONSTRUCTED CONCEPT MAPS

Several features that characterize concept maps have already been discussed in Section III: they are two-dimensional, they proceed from general to specific, they show the relationships among concepts, and they illustrate some hierarchy among the concepts. Given these features, it is not difficult to develop some forms for assessing the concept maps that students complete.

Two forms for assessing concept maps are provided on the next few pages. The first form (A) is designed to give a "large field of view," providing the teacher with a quick overview of maps. The second form (B) provides a more comprehensive scaling of the features of a concept map, including some features not already mentioned. Of course, the second form requires a greater amount of time to use properly, but this is weighed against the advantage of thoroughness. Further, the more comprehensive form indicates weaknesses in the maps, and can thus suggest future instructional needs.

GENERAL OVERVIEW FOR STUDENT-CONSTRUCTED CONCEPT MAPS (FORM A)

	YES	NO	NEEDS WORK
1. Are relationships between concepts indicated on line and are they content correct, that is valid?	( )	( )	( )
2. Are the concepts arranged from general to specific? (Look for the most inclusive concept at the top; examples at the bottom.)	( )	( )	( )
3. Are the concepts linked? (Look for lines between the concepts. The relationship between concepts should be indicated. That is, something should be written on the lines.)	( )	( )	( )
4. Is the map hierarchical? (Look for more inclusive concepts connected to two or more lower or subordinate concepts.)	( )	( )	( )

Figure 16. General Overview for Quick Scoring of Student-Constructed Concept Maps.

COMPREHENSIVE FORM FOR ASSESSING STUDENT-CONSTRUCTED CONCEPT MAPS (FORM B)

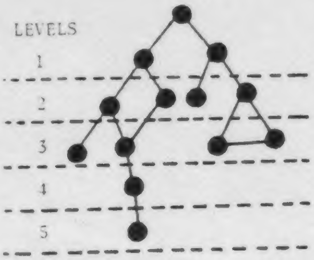
In this form, the features of a concept map are expanded. These additional features reflect a more complete view of concept maps that students develop. They should be used only after the students have had enough exposure to the strategy, and feel confident to expand the strategy.

Ignore all parts of the map for relationships criterion if no relationships are explicitly identified by proper labeling of the connecting line.

RELATIONSHIPS: One point is given for each relationship between two concepts provided the relationship is content correct and explicitly stated. No additional credit is awarded for duplication of the same relationship on the concept map.

HIERARCHY: Points are awarded depending on the degree of hierarchy in the concept map. The number of points given for hierarchy depends upon the number of levels that are identified in the constructed map. Use the map to the right for illustration.

One point is given for at least one correct relationship per level, up until two levels beyond the last branching if the map remains linear.



BRANCHING: The branching of the concept map refers to the level of degree of differentiation among the concepts that are illustrated in the hierarchy. That is, it attempts to rate the degree that specific concepts are connected to more general or inclusive concepts. That rating is as follows:

One point for the first branching where two or more concepts are connected to the concept above.

Three points for any subsequent branching where there is an example of two or more concepts connected to a concept above. The illustrated map above would receive a score of seven; 1 point for Level 1, and three points each for Levels 2 and 3. Note that since no branching occurs in Levels 4 and 5, no further points are awarded for this criterion.

GENERAL TO SPECIFIC: The concept map receives an additional rating for illustrating a general to specific pattern. Whether one concept is more general than the ones below it depends upon the line which connects the two concepts. If no general to specific relationships exist, or less than 10% of the relationships are general to specific, the map receives a score of zero.

If 10 - 29% are correct = 1 point
30 - 49% " = 2 points
50 - 69% " = 3 "
70 - 89% " = 4 "
90 - 100% " = 5 "

CROSS LINKS: Interratedness in a student's concept map indicates an integration of concepts, and is depicted as cross links on the concept map. Cross links show a relationship between concepts on one branch of the hierarchy with concepts on another branch. Notice the two examples of cross links in the illustration above. A rating of one point is given for each cross link showing the integration among concepts. No additional points are awarded for duplication of the same cross link, that is, showing the same integration of concepts.

Figure 17. Comprehensive From for Assessment of Student-Constructed Concept Maps.

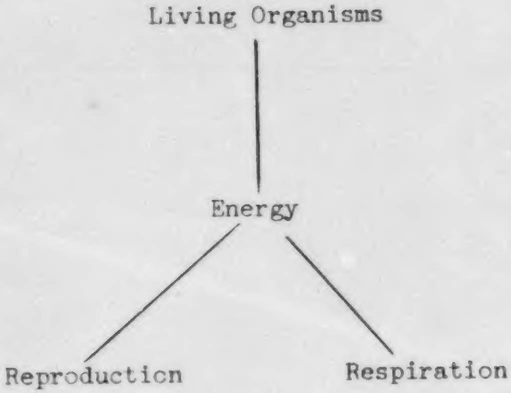
SAMPLES OF STUDENT-CONSTRUCTED CONCEPT MAPS WITH ANNOTATED ASSESSMENTS

The next three pages show examples of concepts maps that students have made during the evaluation phase of our "Learning How to Learn Project." These examples were solicited from seventh grade students during clinical interviews. The interviewees were given a paragraph reading that was based on material that they already had in class. After reading the paragraph, the students were asked to construct concept maps of the reading. The reading used for the sample of students whose maps appear in the following pages is presented below.

In addition to the reconstructed concept maps, an annotated rating, based on the comprehensive scale on page V-4 has been included in order to familiarize the teacher with how this type of rating technique can be used.

> Living things all need energy. Plants and animals use energy for life activities. Some life activities that both plants and animals have are growth, reproduction, respiration, and transport of materials. A life activity found only in green plants is the production of food. Animals cannot produce their own food, so they need the life activity of locomotion to find food.

Figure 18. Sample Paragraph for Clinical Interviews used in the Evaluation of students' Concept Mapping Approaches.



RATING:

Relationships	0	(Student has not identified any connections among the concepts. Since these connections have not been explicitly made, no credit is given for the other criteria as well.)
Hierarchy	0	
Branching	0	
General to Specific	0	
Cross Links	0	

Figure 19A. Student-Constructed Concept Map #1. This map is included to illustrate the importance of the connections among the concepts. Without these connections, no other criterion can be determined, and thus, the map receives a total score of zero.

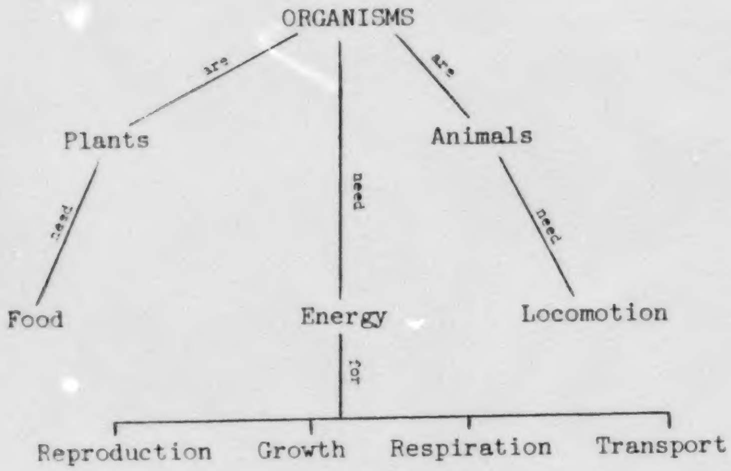

ORGANISMS
are
are
Plants
need
Animals
need
need
Food
Energy
Locomotion
for
Reproduction
Growth
Respiration
Transport

Figure 19B. Student-Constructed Concept Map #2.

RATING:

Relationships	9	(Student has identified nine connections among the concepts represented on the map, and all of these are content correct.)
Hierarchy	2	(Student has identified two levels of hierarchy: from ORGANISMS to PLANTS and ANIMALS and ENERGY; and from ENERGY to REPRODUCTION, GROWTH, etc. One point for Level 1, one point for Level 2, for a total of two points.)
Branching	4	(Student has branched the concepts at the two levels of hierarchy. One point for Level 1, three points for Level 2, for a total of four points.)
General to Specific	5	(All of the concepts and their levels illustrate the general to specific rule, resulting in five points.)
Cross Links	0	(No cross links are indicated on the concept map.)

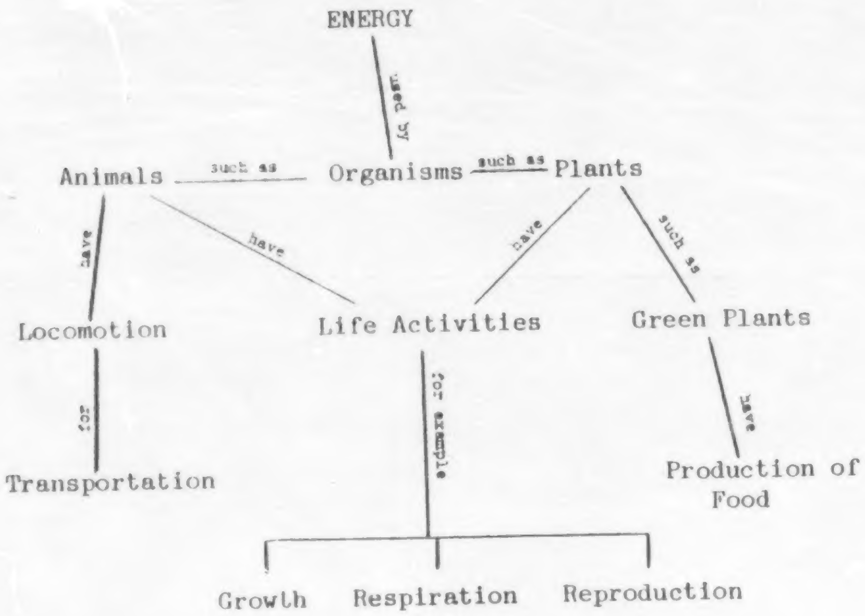

ENERGY
used by
Animals
such as
Organisms
such as
Plants
have
have
have
such as
Locomotion
Life Activities
Green Plants
for
for example
have
Transportation
Production of Food
Growth
Respiration
Reproduction

Figure 19C. Student-Constructed Concept Map #3.

RATING:

Relationships	11	(Student has identified eleven connections among the concepts represented on the map. The connection of LOCOMOTION "for" TRANSPORTATION represents a misconception and thus is not computed in the total.)
Hierarchy	3	(Three levels of hierarchy are identified.)
Branching	7	(No branching at Level 1. Branching is represented at Levels 2, 3, and 4. One point for Level 2, three points each for Levels 3 and 4, for a total of seven points.)
General to Specific	5	(All but the misconception mentioned above show the general to specific rule. This is greater than the 90% level, thus the map is awarded five points.)
Cross Links	1	(One cross link, showing the integration of concepts is represented: ANIMALS-ORGANISMS-PLANTS-LIFE ACTIVITIES.)

EVALUATION OF THE KNOWLEDGE "V" - IDENTIFICATION, DEFINITIONS, AND EXAMPLES OF TERMS

This aspect of the evaluation of the implementation of the "Learning How to Learn Program" in your classroom is a simple, straightforward pencil-paper format. Its objective is to determine if students can identify the parts of the "V," define each of these terms in their own words, and, given an example of a laboratory exercise, identify an example of "record," "concept," "knowledge claim," etc. in a laboratory exercise. The format is given on the next two pages.

You will notice that page V-11 contains two laboratory exercises. These are examples that we have used in our research. For a test that you would devise, one example from work previously done by your students should be used.

NAME: ______________________ DATE: ______________ SCHOOL: ______________

DEFINITIONS AND EXAMPLES OF THE TERMS OF THE "V"

Instructions: Below is an outline of the "V" that we have been using in class. As you know, there are nine terms that are used with the "V". In each of the spaces with a double line (____), fill in the proper term, and write the definitions of that term in the space designated by the single line (___).

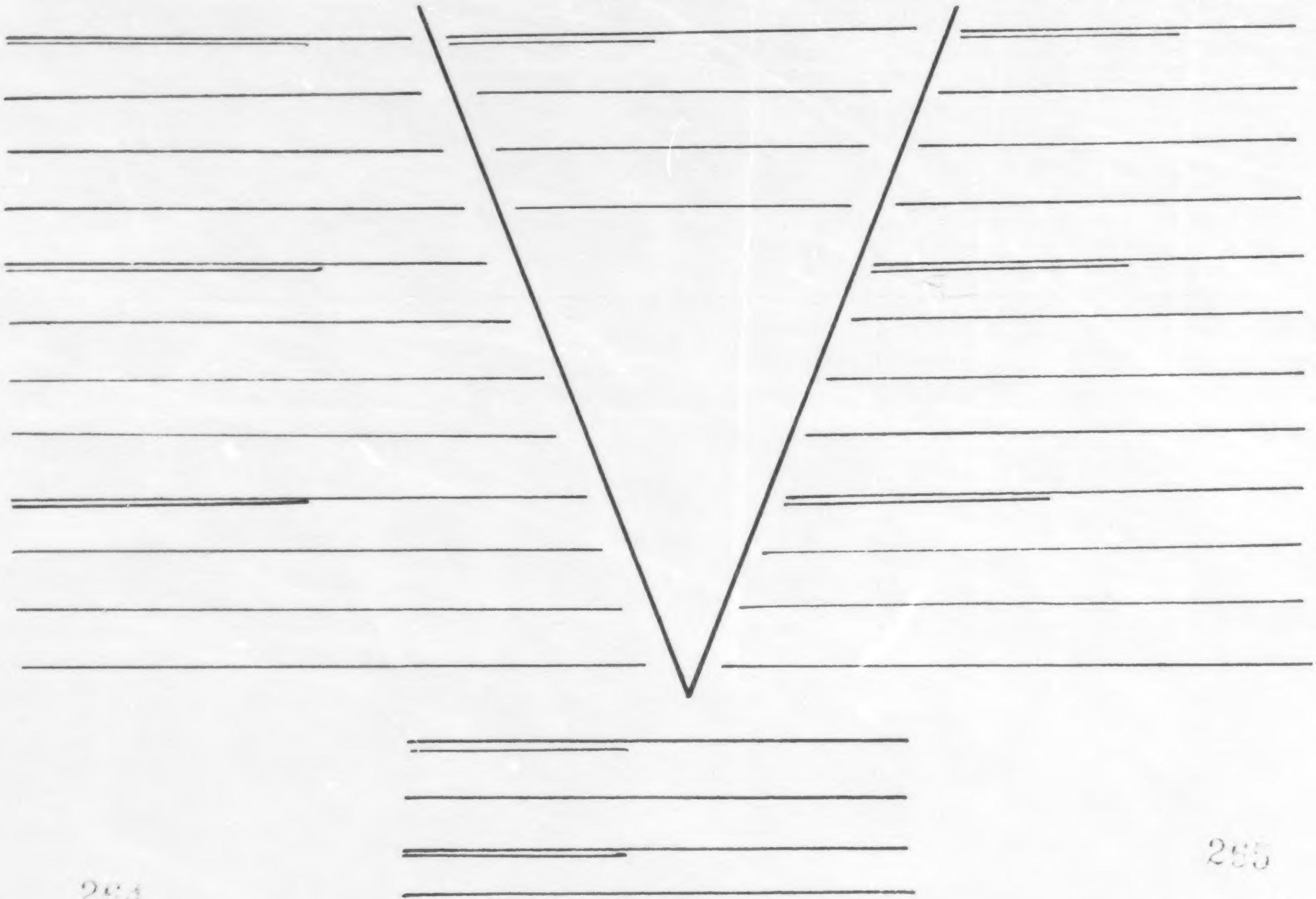


Figure 20A. Assessment of students' understanding of the terms and definitions of the Knowledge "V".

V-10

Instructions: Below is an example of a simple laboratory exercise that is similar to one you have done already in class. Read through the exercise carefully, and then identify which part of the laboratory exercise is an example of each of the terms around the "V".

PROBLEM: Do variations exist in the number of seeds in bean pods?

BACKGROUND: Are there two people in your class who look alike? Even if identical twins are present, the answer to this question will always be that no two people are exactly alike. Natural selection states that all living things show some differences when compared to each other. Scientists have made the statement that there is much variation even among living things that are closely related. Sometimes the variation can be helpful to living things and may give them an advantage over others.

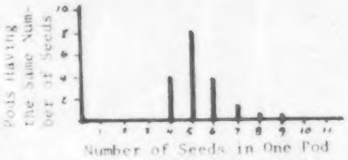
MATERIALS: Fresh bean pods (green or string beans)

PROCEDURE:

1. Open twenty bean pods.
2. Count the number of bean seeds that you find in each. Count all sizes even if they are small.
3. Write down your results below using the mark (/) to show the number of pods having those number of seeds listed. Then prepare a bar graph of your results.

NUMBER OF SEEDS IN ONE POD

	1	2	3	4	5	6	7	8	9	10	11
Pods Having Same Number of Seeds				////	//// ////	////	//	/	/		



CONCLUSIONS: Based on the results, variations in the number of seeds in bean plants does exist. The number of seeds could be useful to the organism because it gives them an advantage over other organisms of the same species.

Figure 20B. Two examples of laboratory exercises used to determine whether students can identify examples of terms of the Knowledge "V".

INSTRUCTIONS: Below is an example of a laboratory exercise that is similar to one that you have already completed in class. Read through the exercise carefully. Then, identify by underlining or circling that part of the exercise that corresponds to each of the terms around the "V". Label these parts using the terms of the "V".

FIND OUT: How much heat is lost by hot iron washers when they are placed in water?

BACKGROUND: The kinetic molecular model states that the amount of heat energy in a substance is related to the kinetic energy of the molecules and the number of molecules in that substance. As heat is given off by a substance, the molecules in that substance move more slowly. As heat is added to a substance, the molecules move more quickly. When two substances of different temperatures are brought near each other or are mixed, heat from the warmer substance is given off to the cooler substance until both substances reach the same temperature. The amount of heat lost by the warmer substance is equal to the amount of heat gained by the cooler substance.

A thermometer is an instrument that measures the average speed of the molecules in a substance. To measure the amount of heat, a person can use a calorimeter. Basically, a calorimeter is nothing more than an insulated container with a thermometer fitted into it. The name "calorimeter" comes from the fact that heat is measured in calories -- a calorie being the amount of heat that will raise the temperature of one gram of water one degree Celsius.

MATERIALS: cardboard, Celsius thermometer, ring stand and ring, set of known masses, styrofoam cups, wire gauze, iron washers, balance, beaker, string, tongs, bunsen burner, matches.

PROCEDURE:

1. Make a simple calorimater by placing one styrofoam cup inside another. Make a lid from a piece of cardboard. Punch a hole in the lid and place the thermometer in the hole.
2. Using the balance, find the mass of the entire calorimeter, including the thermometer. Write this mass (M_1) in the space below.
3. Half fill the calorimeter with water. Find the mass of the calorimeter with the water in it. Write the mass of the calorimeter and water (M_2) in the space below.
4. Measure the temperature of the water inside the calorimeter. Write this temperature as the initial temperature of the water (T_1) in the space below.
5. Tie about ten iron washers together with a piece of string. Set a beaker of water over the bunsen burner. When the water boils, place the washers in the water. Leave them in the water for several minutes. Then, using the tongs, quickly remove the washwers from the beaker and place them in the calorimeter. Observe and write down the highest temperature reached on the thermometer in the calorimeter. Write this temperature (T_2) in the space below.

OBSERVATIONS AND DATA:

M_1 = 120 grams
T_1 = 24 °C
M_2 = 210 grams
T_2 = 27 °C

Compute the following:

Mass of the water ($M_2 - M_1$) = 90 grams

Change in Temperature ($T_2 - T_1$) = 3 °C

Calories Gained by the Water [$(M_2 - M_1) \times (T_2 - T_1)$] = 270 calories

CONCLUSIONS: The washers lost heat to the water. Since the water gained 270-calories of heat, the washers must have lost an equal amount of heat (270-calories).

ASSESSMENT OF STUDENT-CONSTRUCTED "V'S"

Although the title indicates that this evaluation method is intended for use in assessing student-constructed "V's", it is important to remember that the "V" is also a pre-teaching tool, and thus has applicability there as well.

The objective of this part of the evaluation is to determine how good are the "V's" that students prepare. The first form of the evaluation gives an overall picture of the "V" and attempts to locate large holes in the students' work. In other words, it gives the teacher a large field of view so that a more general picture can be determined. The second form is more comprehensive. Its function is to give the teacher a closer look at each of the parts of the "V" and to assess the students' performances at developing a focus question, at recognizing the major event, at checking the records and transformations, etc. For each of these parts of the "V" a range of scores can be assigned. The range is constructed from zero (0) which indicates that there has been nothing written for that part of the "V", through an optimal score for that part. This form can function in two ways. First, it can help track the progress of a student over time in each part of the "V". The "Progress Sheet" on page V-17 can be used to follow individual student progress to see where major difficulties still stand out, and where the teacher should concentrate in subsequent work with individual students. Second, the total of all the parts of the "V" can be used to provide a single mark for laboratory exercises. This mark is represented at the bottom of the "Progress Sheet."

GENERAL OVERVIEW OF STUDENT-CONSTRUCTED "V's" (FORM A)

This checklist gives the teacher a general assessment technique for evaluating student-constructed "V's". As the students and the teacher gain more proficiency with the range and use of the "V", the teacher will probably want to use Form B on the next page. However, this form will serve the purpose of initial assessment.

Figure 21. General Assessment of Student-Constructed "V's".

	Yes	No	Needs Work
1. Does the focus question attempt to relate two or more concepts?	☐	☐	☐
2. Does the focus question relate to what going to occur in the laboratory exercise?	☐	☐	☐
3. Has the student properly identified the major event?	☐	☐	☐
4. Are relevant concept identified?	☐	☐	☐
5. Have relevant principles and theory been identified?	☐	☐	☐
6. Has the student made adequate records and transformations?	☐	☐	☐
7. Is the knowledge claim clear, complete, and consistent with the focus question?	☐	☐	☐

COMPREHENSIVE FORM FOR ASSESSING STUDENT-CONSTRUCTED "V's"

Focus Question:

0 - no focus question is identified.

1 - a question is identified, but does not focus upon the objects and the major event OR the conceptual side of the "V".

2 - a focus question is identified; includes concepts, but does not suggest objects or the major event OR the wrong objects and event are identified in relation to the rest of the laboratory exercise.

3 - a clear focus question is identified; includes concepts to be used and suggests the major event and accompanying objects.

Objects/Event:

0 - no objects or event is identified.

1 - the major event OR the objects are identified and is consistent with the focus question, OR an event and objects are identified, but are inconsistent with the focus question.

2 - the major event with accompanying objects is identified, and is consistent with the focus question.

3 - same as above, but also suggests what records will be taken.

Theory, Principles, and Concepts:

0 - no conceptual side is identified.

1 - a few concepts are identified, but without principles and theory, or a principle written is the knowledge claim sought in the laboratory exercise.

2 - concepts and at least one type of principle (conceptual or methodological) OR concepts and a relevant theory is identified.

3 - concepts and two types of principles are identified, OR concepts, one type of principle, and a relevant theory are identified.

4 - concepts, two types of principles, and a relevant theory are identified.

Records/Transformations:

0 - no records or transformations are identified.

1 - records are identified, but are inconsistent with the focus question or the major event.

2 - records OR transformations are identified, but not both.

3 - records are identified for the major event; transformations are inconsistent with the intent of the focus question.

4 - records are identified for the major event; transformations are consistent with the focus question and the grade level and ability of the student.

Knowledge Claim:

0 - no knowledge claim is identified.

1 - a claim that is unrelated to the left-hand side of the "V".

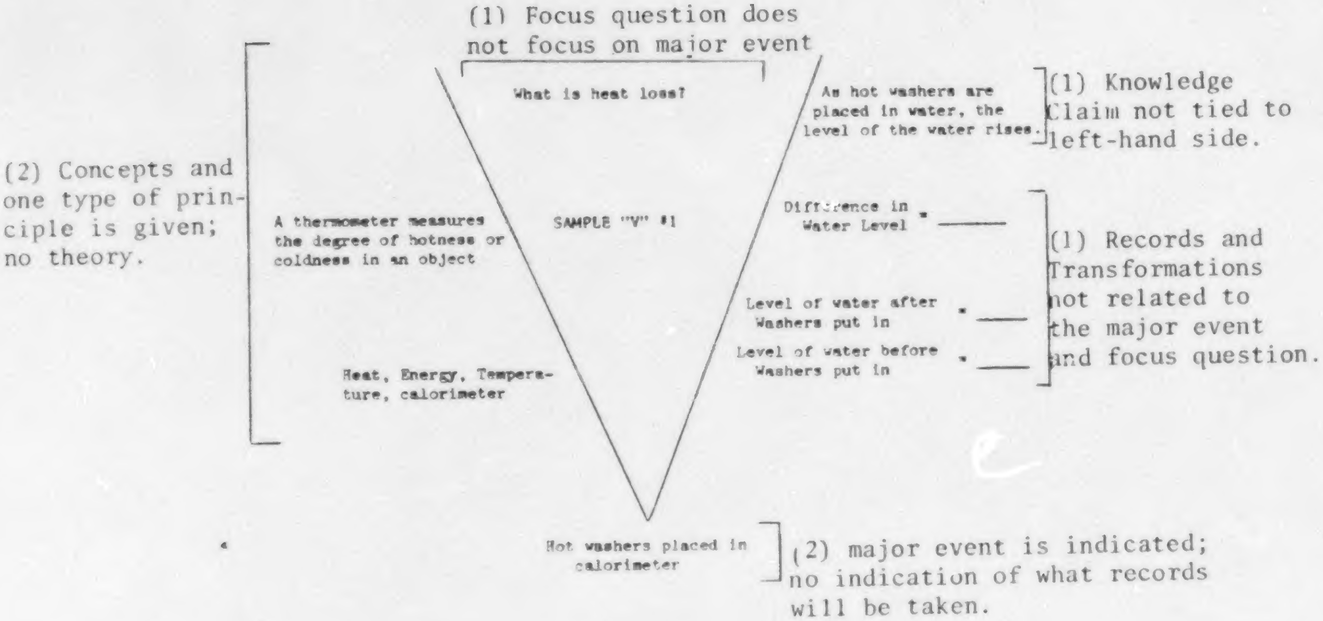
2 - a knowledge claim that includes a concept that is used in an improper context OR any generalization that is inconsistent with the records and transformations.

3 - a knowledge claim that includes the concepts from the focus question and is derived from the records and transformations.

4- same as above, but the knowledge claim leads to a new focus question.

Below and on the next page are three examples of "V's" for the same laboratory exercise involving heat loss and heat gain. Each "V" is completed and annotated to indicate what mark that part of the "V" would receive based on the criteria on page V-14. The mark for that section appears in parentheses at the start of each annotation.

On page V-17 these three sample "V's" are recorded on the "Student Progress Sheet."


What is heat loss?
SAMPLE "V" #1
A thermometer measures the degree of hotness or coldness in an object
Heat, Energy, Temperature, calorimeter
As hot washers are placed in water, the level of the water rises.
Difference in Water Level = ______
Level of water after Washers put in = ______
Level of water before Washers put in = ______
Hot washers placed in calorimeter

(1) Focus question does not focus on major event

(2) Concepts and one type of principle is given; no theory.

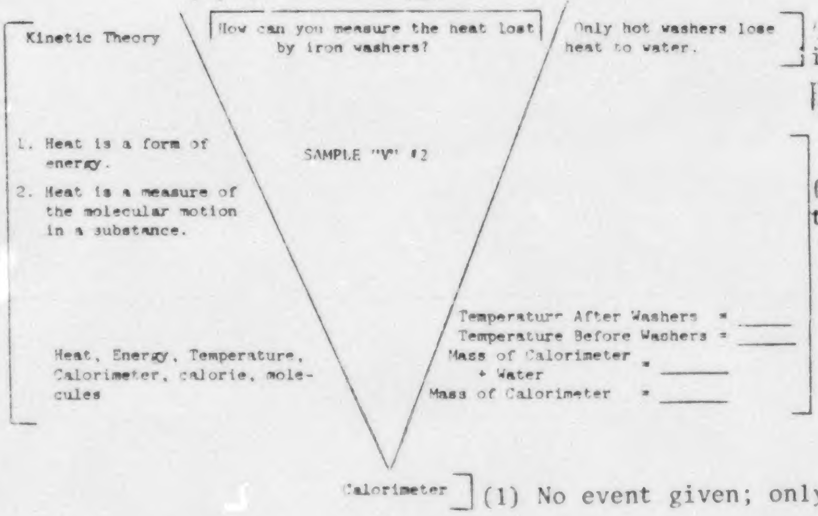
(1) Knowledge Claim not tied to left-hand side.

(1) Records and Transformations not related to the major event and focus question.

(2) major event is indicated; no indication of what records will be taken.

Figure 22A. Sample V#1 with Annotated Evaluative Rating for a total of seven points out of a possible eighteen.

(2) no event suggested


Kinetic Theory
How can you measure the heat lost by iron washers?
Only hot washers lose heat to water.
1. Heat is a form of energy.
2. Heat is a measure of the molecular motion in a substance.
SAMPLE "V" #2
Heat, Energy, Temperature, Calorimeter, calorie, molecules
Temperature After Washers = ____
Temperature Before Washers = ____
Mass of Calorimeter + Water = ____
Mass of Calorimeter = ____
Calorimeter

(3) Concepts, one type of principle, and a relevant theory.

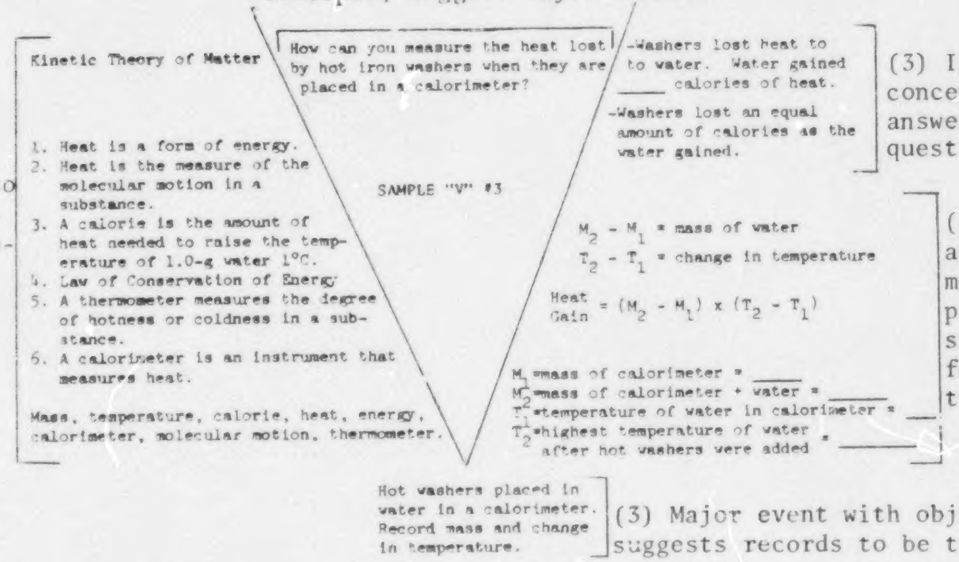
(2) Generalization is too broad. Improper context for "only."

(2) No transformations made.

(1) No event given; only object.

Figure 22B. Sample "V" #2 with a total score of ten out of a possible eighteen.

(3) Focus question relates concepts; suggest major event


Kinetic Theory of Matter
How can you measure the heat lost by hot iron washers when they are placed in a calorimeter?
-Washers lost heat to to water. Water gained ____ calories of heat.
-Washers lost an equal amount of calories as the water gained.
1. Heat is a form of energy.
2. Heat is the measure of the molecular motion in a substance.
3. A calorie is the amount of heat needed to raise the temperature of 1.0-g water 1°C.
4. Law of Conservation of Energy
5. A thermometer measures the degree of hotness or coldness in a substance.
6. A calorimeter is an instrument that measures heat.
SAMPLE "V" #3
$M_2 - M_1$ = mass of water
$T_2 - T_1$ = change in temperature
Heat Gain = $(M_2 - M_1) \times (T_2 - T_1)$
M_1 = mass of calorimeter = ____
M_2 = mass of calorimeter + water = ____
T_1 = temperature of water in calorimeter = ____
T_2 = highest temperature of water after hot washers were added = ____
Mass, temperature, calorie, heat, energy, calorimeter, molecular motion, thermometer.
Hot washers placed in water in a calorimeter. Record mass and change in temperature.

) Concepts, two
pes of princi-
es, and a rele-
nt theory
ven

(3) Includes concepts; answers focus question.

(4) Records and transformations complete; consistent with focus question.

(3) Major event with objects; suggests records to be taken.

Figure 22C. Sample "V" #3 with a total score of seventeen out of a possible eighteen.

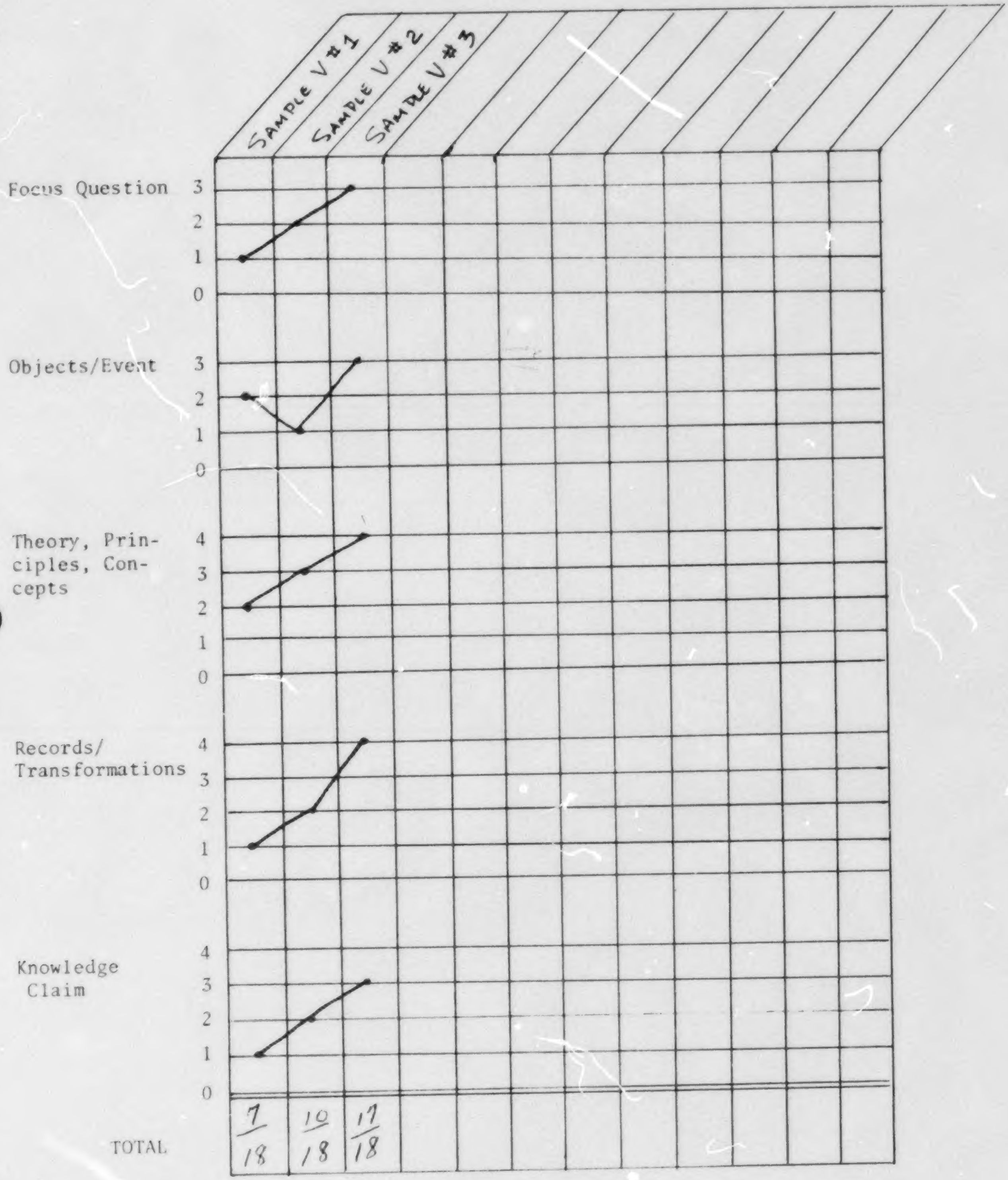


Figure 23. The Student Progress Sheet. The purpose of this sheet is to provide the teacher with a quick visual overview of individual student progress in relation to the parts of the "V". The total score at the bottom provides a single defensible rating for the student's laboratory exercise.

USING THE "V" IN SEQUENCE

This part of the evaluation attempts to determine if the knowledge claims from previous experiments can operate as conceptual principles in subsequent experiments. In "V" #1 below, the student reaches the claim that carbon dioxide is given off during fermentation. Knowing that, the student can use that information as conceptual principles for determining other knowledge claims about yeast fermentation. In "V" #3 the student takes the knowledge claims from the previous two experiments and uses them as conceptual principles for the new focus question. Each "V" can be evaluated on the basis of the criteria already identified on page V-14 in this handbook. The teacher should, however, concentrate on whether these previous knowledge claims are being used as conceptual principles in the subsequent experiments.

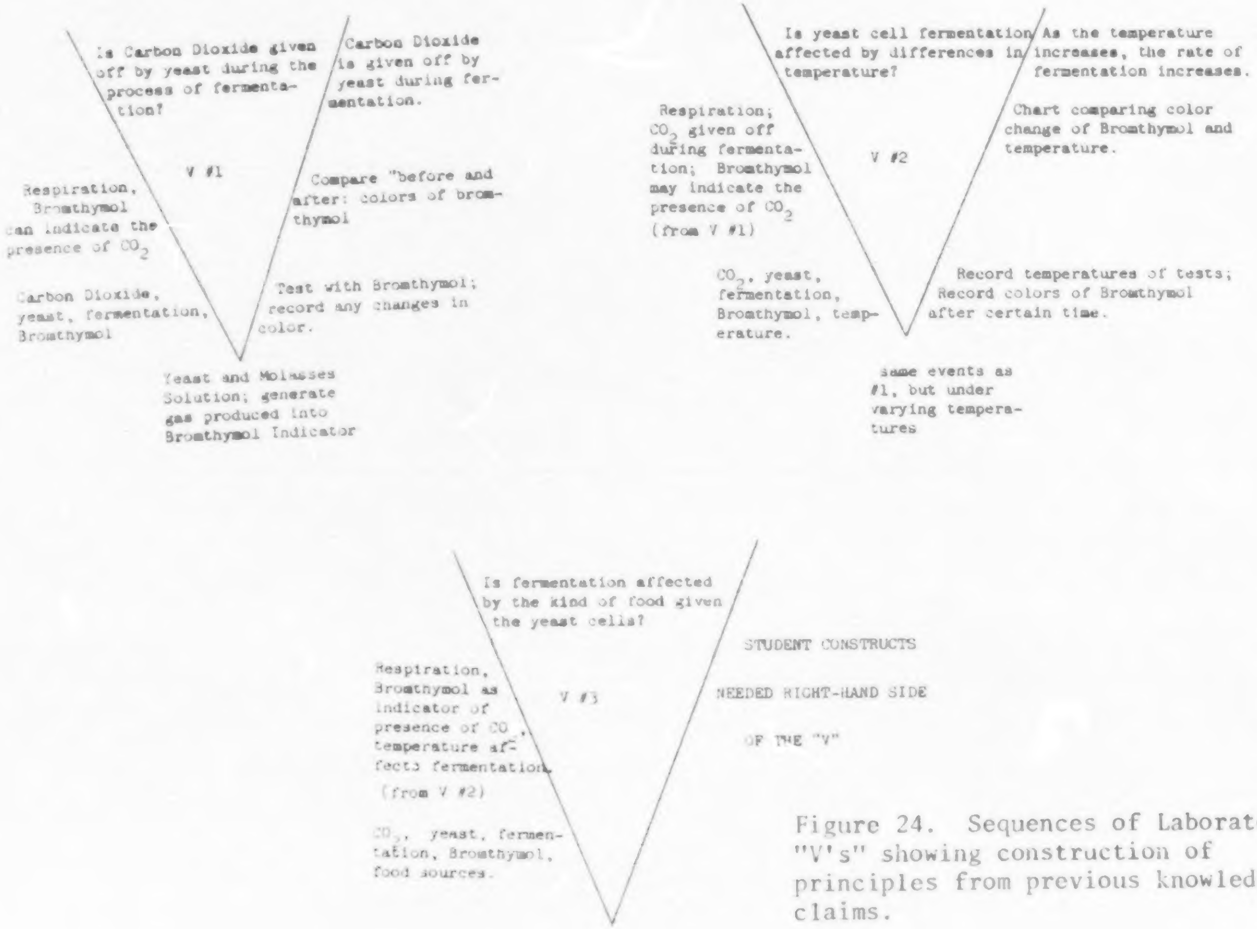

Is Carbon Dioxide given off by yeast during the process of fermentation?
Carbon Dioxide is given off by yeast during fermentation.
V #1
Respiration, Bromthymol can indicate the presence of CO_2
Compare "before and after: colors of bromthymol
Carbon Dioxide, yeast, fermentation, Bromthymol
Test with Bromthymol; record any changes in color.
Yeast and Molasses Solution; generate gas produced into Bromthymol Indicator
Is yeast cell fermentation affected by differences in temperature?
As the temperature increases, the rate of fermentation increases.
Respiration; CO_2 given off during fermentation; Bromthymol may indicate the presence of CO_2 (from V #1)
V #2
Chart comparing color change of Bromthymol and temperature.
CO_2, yeast, fermentation, Bromthymol, temperature.
Record temperatures of tests; Record colors of Bromthymol after certain time.
Same events as #1, but under varying temperatures
Is fermentation affected by the kind of food given the yeast cells?
Respiration, Bromthymol as indicator of presence of CO_2, temperature affects fermentation (from V #2)
V #3
STUDENT CONSTRUCTS
NEEDED RIGHT-HAND SIDE
OF THE "V"
CO_2, yeast, fermentation, Bromthymol, food sources.

Figure 24. Sequences of Laboratory "V's" showing construction of principles from previous knowledge claims.

INTEGRATION OF THE "V" AND CONCEPT MAPPING

At this stage of the evaluation of the introduction of these strategies into the classroom, the student should have a firm grasp of both techniques. What time is appropriate to integrate concept mapping and the "V" depends upon a number of conditions: ability of the students, pacing of the class work, and how intense the exposure to these strategies has been previous to this time. However, when the teacher feels that the students are ready, the integration can begin.

In our studies, one teacher eased into this integration by having students construct small concept maps for the "background" information of an experiment. This exercise was given for homework or in the pre-lab discussion. After the experiment was completed, the students proceeded to construct the "V" for the exercise. After a few trials with this method, the students were asked to take this preliminary concept map and make it the left-hand side of the "V".

Evaluation of the integration of both concept mapping and the "V" involves taking certain aspects of the assessment techniques already mentioned in this handbook. Here then are some general guidelines as suggestions for implementing the integration:

1. When assessing a student's "V" delete "Theory, Principles, and Concepts" from the criteria for evaluating the "V" (page V-14).
2. Substitute either the general format for assessing concept maps (Form A), or the more comprehensive (Form (B). It is recommended that the more general form be used at first, and then switch to the more comprehensive form as students become more familiar with the integration.
3. If the students have already come this far with these strategies, it is not recommended that the teacher use Form A for assessing the "V". Form A is too general to provide the kind of specificity that Form B provides.

CONCEPTUAL QUESTIONS: USE OF THE "V" AND CONCEPT MAPPING

As in the previous section, the student should be completely familiar with the strategies of concept mapping and the Knowledge "V". This section of the handbook attempts to suggest techniques that can be used to determine if the strategies have had any effect on meaningful learning (Section II).

How students learn is affected to some degree by the kinds of questions which they anticipate on tests and quizzes. If the students are asked only questions that require rote memorization, and if they have experienced success by learning that way, then there will be less incentive for them to learn in a meaningful fashion.

The technique that we advocate involves the construction of what can be called "conceptual questions." There are not what some may think of as "thought questions" or "brain teasers." Answering a conceptual question requires that students employ meaningfully learned concepts, facilitated through the use of the strategies of concept mapping and the Knowledge "V".

Although it is highly improbable to devise questions that totally eliminate the rote mode of learning, it is possible and desirable to devise questions that minimize this factor and which are more conducive to being answered by the student who has learned meaningfully. These kinds of questions can also be used in a variety of situations, including review sessions, independent study, as well as test construction by the teacher.

Two examples of conceptual questions which were used in our research are described in the next few pages. Both involved a description of an experimental event which paralleled one that the students had previously done in class, and which contained concepts that the learners had already encountered. The first example illustrates how a laboratory exercise already completed can pave the way for the construction of a conceptual question. The second example relies on a different conceptual system (atomic theory, in this case) to offer an explanation for an event usually associated with electricity. Following the description of each example, the method for evaluation of the questions is given.

CONSTRUCTING CONCEPTUAL QUESTIONS: EXAMPLE #1 (THE WINEBOTTLE)

The following is a method for constructing conceptual questions. This first example will be used to illustrate each step of the method.

1. Select an experimental event that the students have been exposed to, and construct a concept map for the left-hand side of the "V" if one has not already been constructed. (See Figure 25 below.)

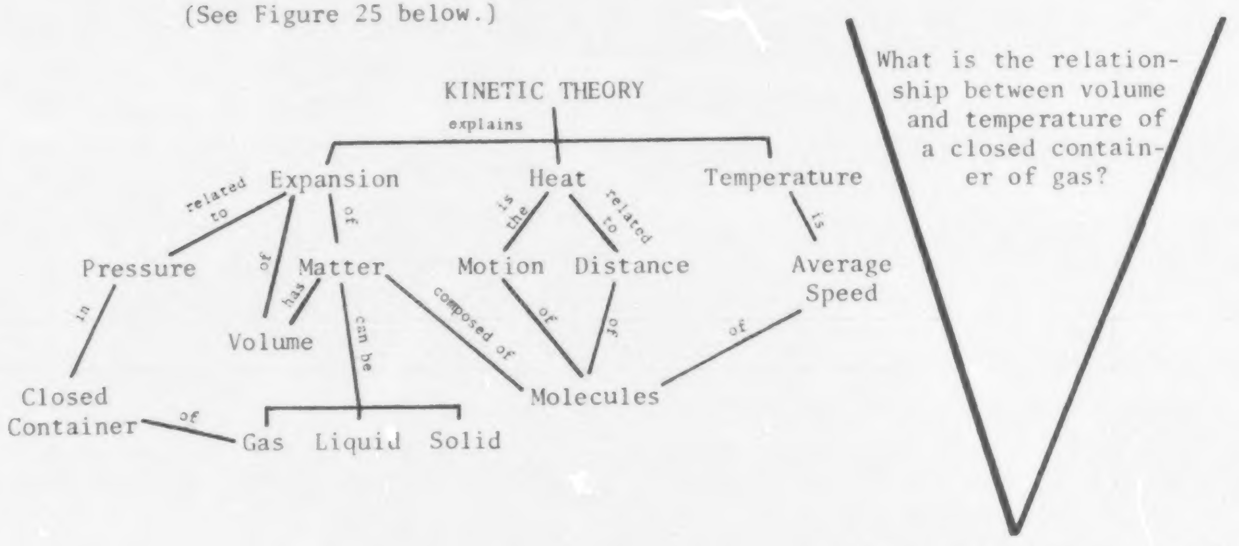

KINETIC THEORY
explains
Expansion
Heat
Temperature
related to
of
of
is the
related to
is
Pressure
Matter
Motion
Distance
Average Speed
in
has
can be
composed of
of
of
of
Volume
Closed Container
of
Gas
Liquid
Solid
Molecules
What is the relationship between volume and temperature of a closed container of gas?
Flask with thermometer and tube with water droplet inside. Heat in bath of hot water. Record changes in temperature and height of water droplet.

Figure 25: Incomplete "V" with Concept Map for purposes of constructing conceptual questions.

2. Select another experimental event for which the same concepts would be relevant. In this example, the event was a capped winebottle that had been moved from the refrigerator to a sunny windowsill.

3. Construct a conceptual answer to the question to anticipate the kinds of conceptual links that the students might offer in their explanations. "Dissect" that explanation, picking out those

sentences which indicate a link between or among concepts. For instance, your anticipated explanation might include such sentences as:

EXPANSION IS DUE TO AN INCREASE IN THE DISTANCE BETWEEN MOLECULES,

HEAT IS DIRECTLY RELATED TO THE AMOUNT OF MOTION OF THE MOLECULES IN A SUBSTANCE, or

THE PRESSURE OF A GAS INSIDE A CLOSED CONTAINER INCREASES AS THAT GAS IS HEATED.

4. In addition to the correct conceptual connections that should be anticipated, the teacher should also prepare a list of misconceptions, commonly held by students.

AS HEAT IS ADDED TO A SUBSTANCE, THE MOLECULES EXPAND,

TEMPERATURE AND HEAT MEASURE THE SAME THING, or

GASES ARE HOTTER THAN SOLIDS.

5. The actual test question should include four elements consistent with the information above: a clear focus question, a major event, some record of that event, and the concepts necessary to sort out the event and answer the question. Below is an example of a conceptual question used in our research. Please notice that all of the necessary elements are present.

DIRECTIONS: Read the paragraph below very carefully, and then do the the following:

-construct a concept map which includes the following concepts: kinetic theory, heat, temperature, gas, molecules, volume, pressure, and expansion.

-using that concept map as a guide, and including as many of the concepts into your answer as you can, explain why the cork popped out of the bottle.

An empty wine bottle is left in the refrigerator overnight. In the morning it is taken out. A cork is stuck in the mouth of the bottle, and the bottle is left on the windowsill where the warm rays of the Sun can hit it. Several minutes later, the cork pops right out of the bottle.

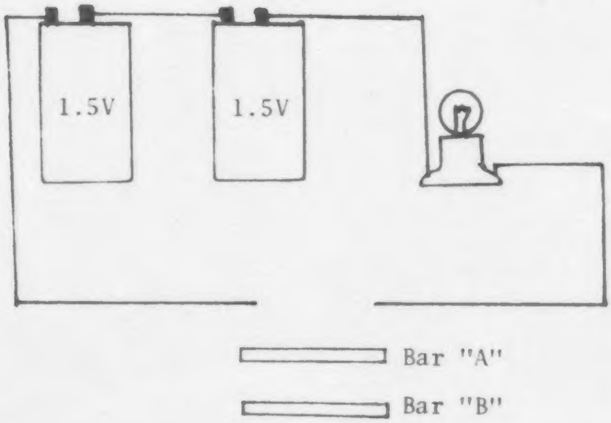
6. Several variations of this kind of question is, of course, possible, but the major elements mentioned already should be included. You may, for instance, decide that you do not want your students to construct a concept map as part of the answer. Although the constructed concept map may be helpful in indicating areas where misconceptions exist, our research seems to demonstrate that the making of a concept map is not necessarily imperative to answering the question.*

7. One final feature that our research has shown to be important should be considered. In our attempts to construct conceptual questions, it has been found that the list of concepts must include one superordinate concept under which all the others can be subsumed. In the example given above, that superordinate concept was "kinetic theory." In the next example, it is the "atomic theory," implied because of the presence of the concepts "electron" and "proton."

CONSTRUCTION CONCEPTUAL QUESTIONS: EXAMPLE #2 (ELECTRICITY)

Using the method described in this section, another example of conceptual questions was designed during our research. Again, the major elements are present: a clear focus question, a major event, some record of that event, and the concepts necessary for the student to answer the question. On the next page the question that was given to the students is provided.

*This is consistent with our thesis that concept mapping is a heuristic device, needed only to facilitate meaningful learning. Once the meaningful learning has occurred, the construction, or re-construction, of a concept map may not be necessary.



The apparatus shown in the figure above was set up by a science teacher. Bar "A" and Bar "B" are exactly the same size, but are composed of different materials. When Bar "A" is use to complete the circuit, the bulb lights up very dimly. When Bar "B" is used to complete the circuit, the bulb lights up brightly.

QUESTION: What must be happening inside Bar "A" that is different than what is happening inside Bar "B"? Use as many of the following concepts as you can to answer this question, or include any other concepts that you feel necessary to answer the question. The concepts include: attraction, conductor, charge, electron, insulator, resistance, proton.

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Novak, Joseph D. "Biology Teaching Practices Based on Application of Learning Psychology and Philosophy of Science." *The American Biology Teacher* (in press), 1980.

Novak, Joseph D. "Progress in Application of Learning Theory." *Theory into Practice,* vol. 19, no. 1, Winter, 1980, pp. 58-65.

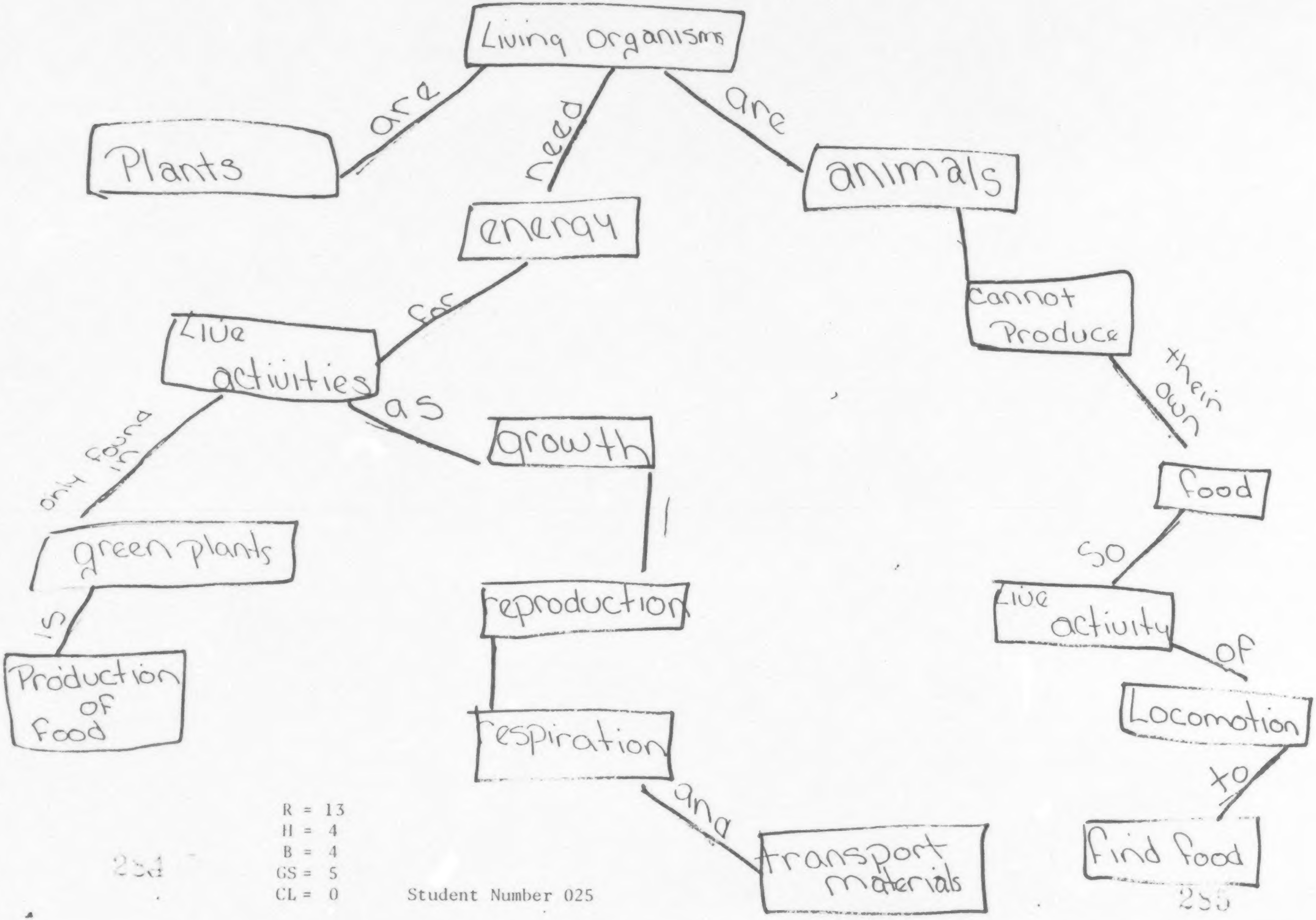
Novak, Joseph D. "Effective Science Instruction: The Achievement of Shared Meaning." submitted to *Australian Science Teachers Journal.*

APPENDIX II

Sample concept maps from clinical interviews and class assessments (1979-1980) in Trumansburg, and Vestal. Each map is identified by the student number, and is rated according to the criteria for assessing concept maps (Appendix I, Section III-4). The following key is provided to identify each criterion of the assessment instrument:

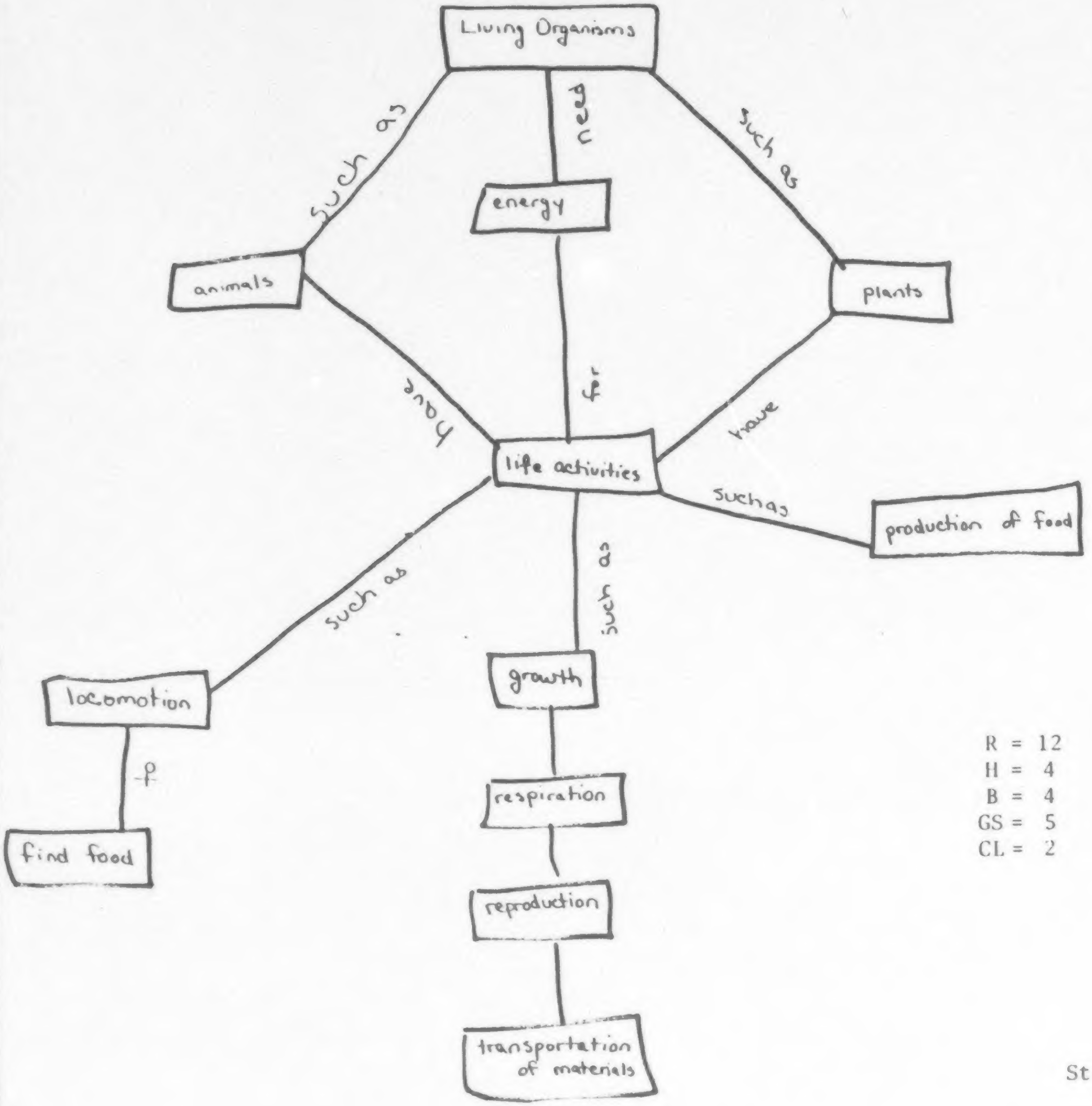
R = relationships identified
H = hierarchy
B = branching
GS = general to specific
CL = cross links

Two sample clinical interviews involving the construction of concept maps. First one from a student in Trumansburg, the second from a student in Vestal.


Living organisms
are
Plants
need
energy
are
animals
for
Live activities
cannot Produce
their own
food
as
growth
only found in
green plants
is
Production of Food
reproduction
respiration
and
transport materials
so
Live activity
of
Locomotion
to
find food

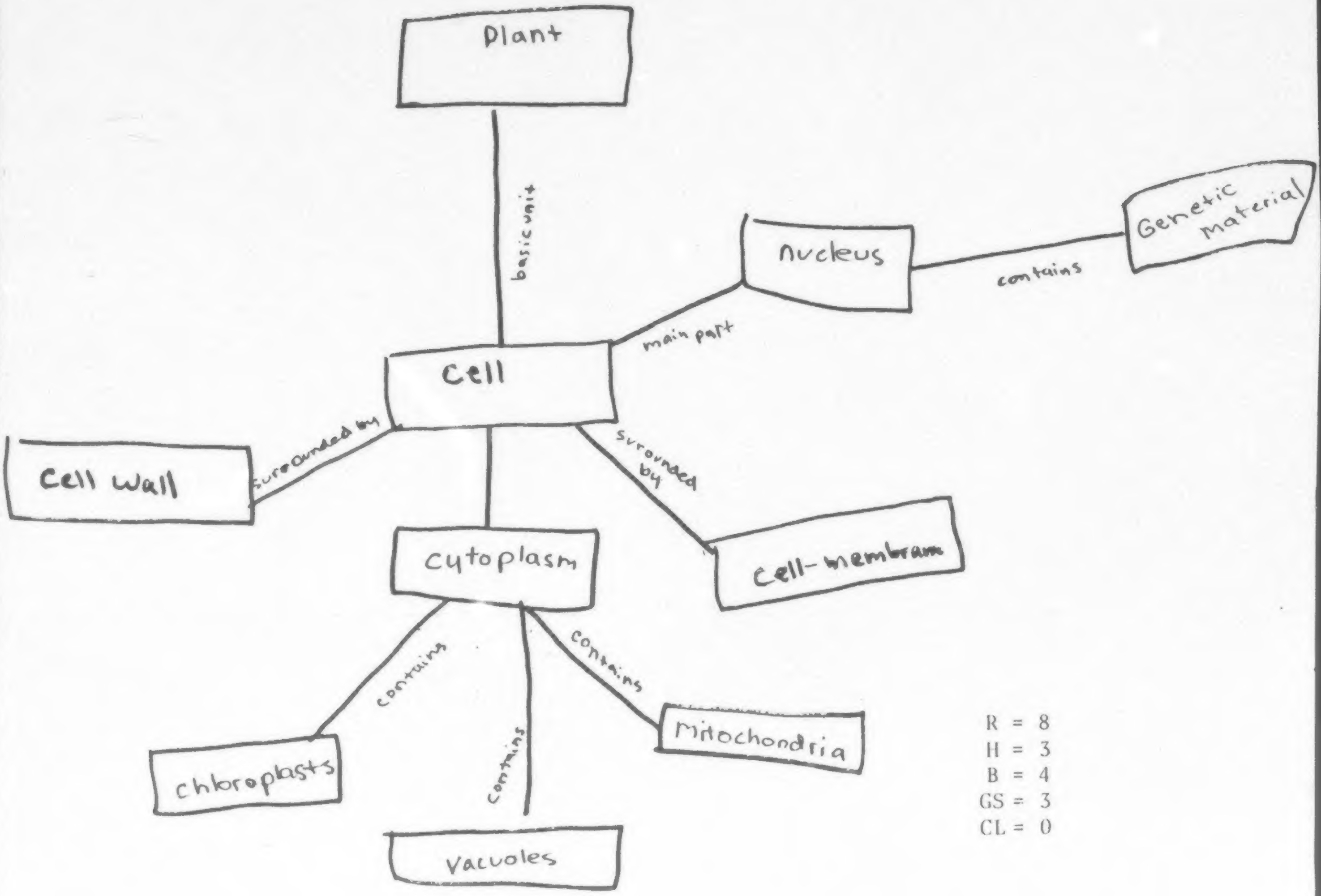
R = 13
H = 4
B = 4
GS = 5
CL = 0

Student Number 025


Living Organisms
such as
need
such as
energy
animals
plants
have
for
have
life activities
suchas
production of food
such as
such as
locomotion
growth
f
find food
respiration
reproduction
transportation of materials

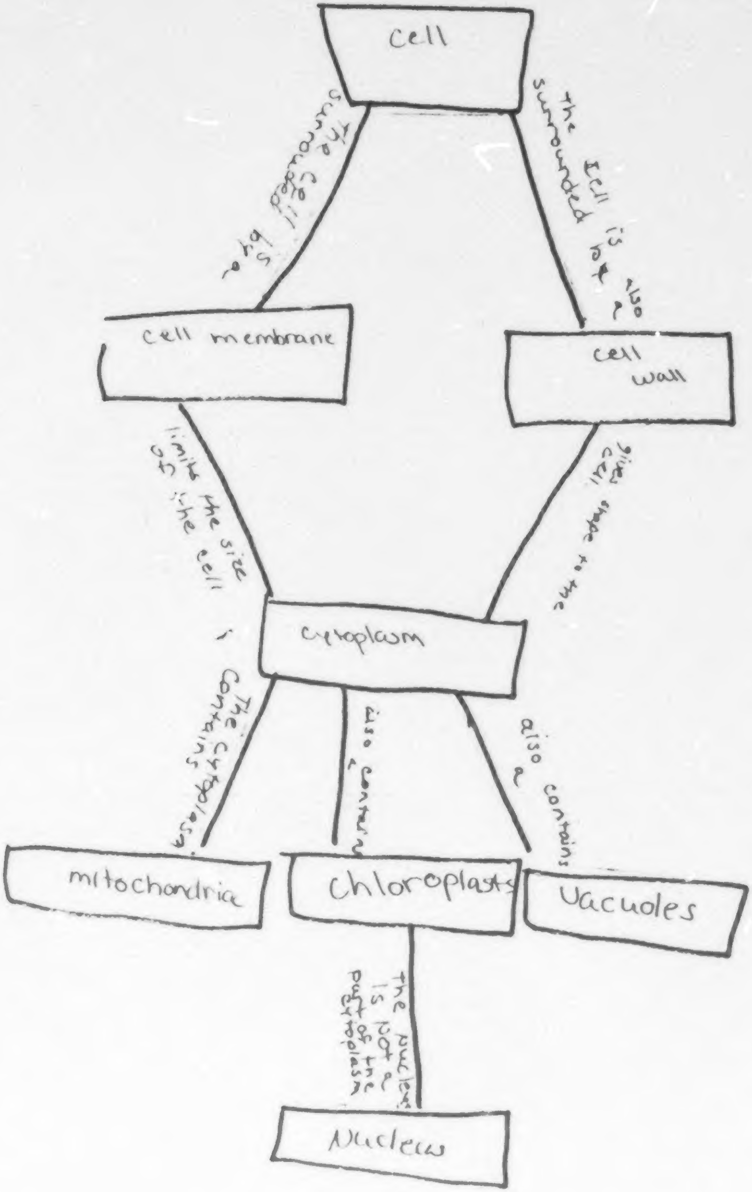
R = 12
H = 4
B = 4
GS = 5
CL = 2

Student Number 016


Plant
basic unit
Cell
main part
nucleus
contains
Genetic material
surrounded by
Cell Wall
surrounded by
Cell-membrane
cytoplasm
contains
chloroplasts
contains
Vacuoles
contains
Mitochondria

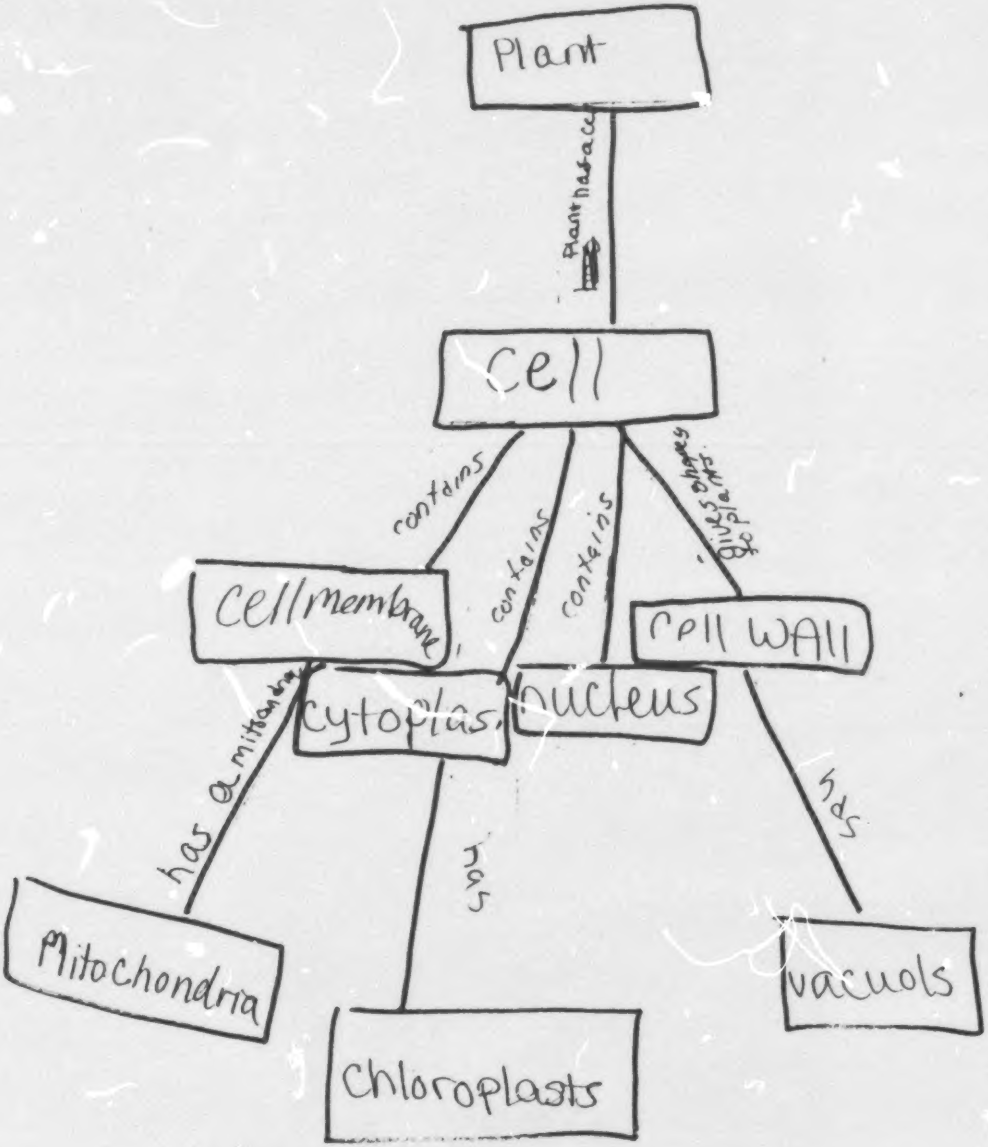
R = 8
H = 3
B = 4
GS = 3
CL = 0

Student Number 261


cell
The cell is surrounded by a
The cell is also surrounded by a
cell membrane
cell wall
limits the size of the cell
gives shape to the cell
cytoplasm
The cytoplasm contains
also contains a
also contains a
mitochondria
Chloroplasts
Vacuoles
The Nucleus is not a part of the cytoplasm
Nucleus

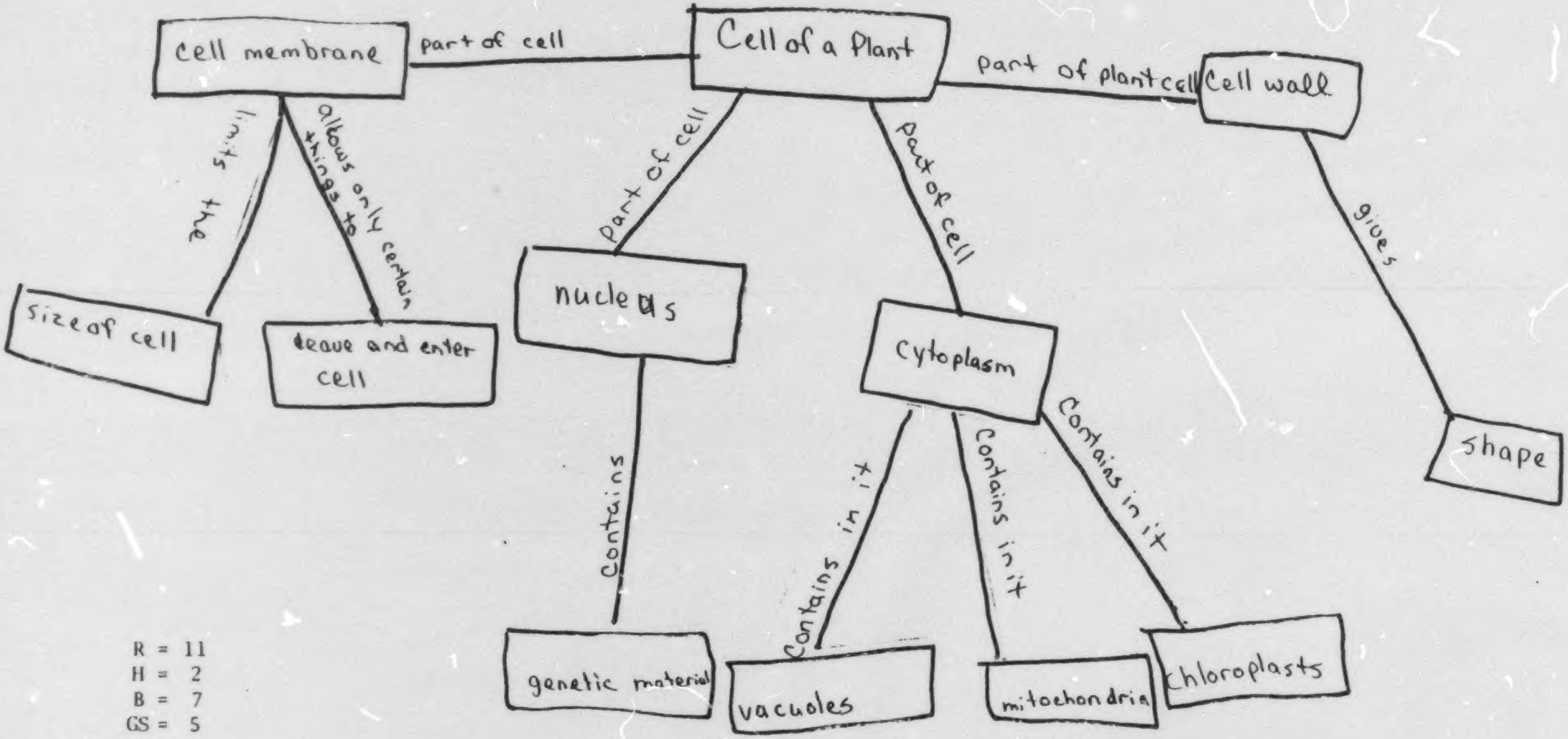
R = 5
H = 2
B = 4
GS = 3
CL = 0

Student Number 284


Plant
Plant has a cell
Cell
contains
contains
contains
gives shapes to plants.
Cell membrane
Cell WAll
Cytoplas.
nucleus
has a mitochondria
has
has
Mitochondria
Chloroplasts
vacuols

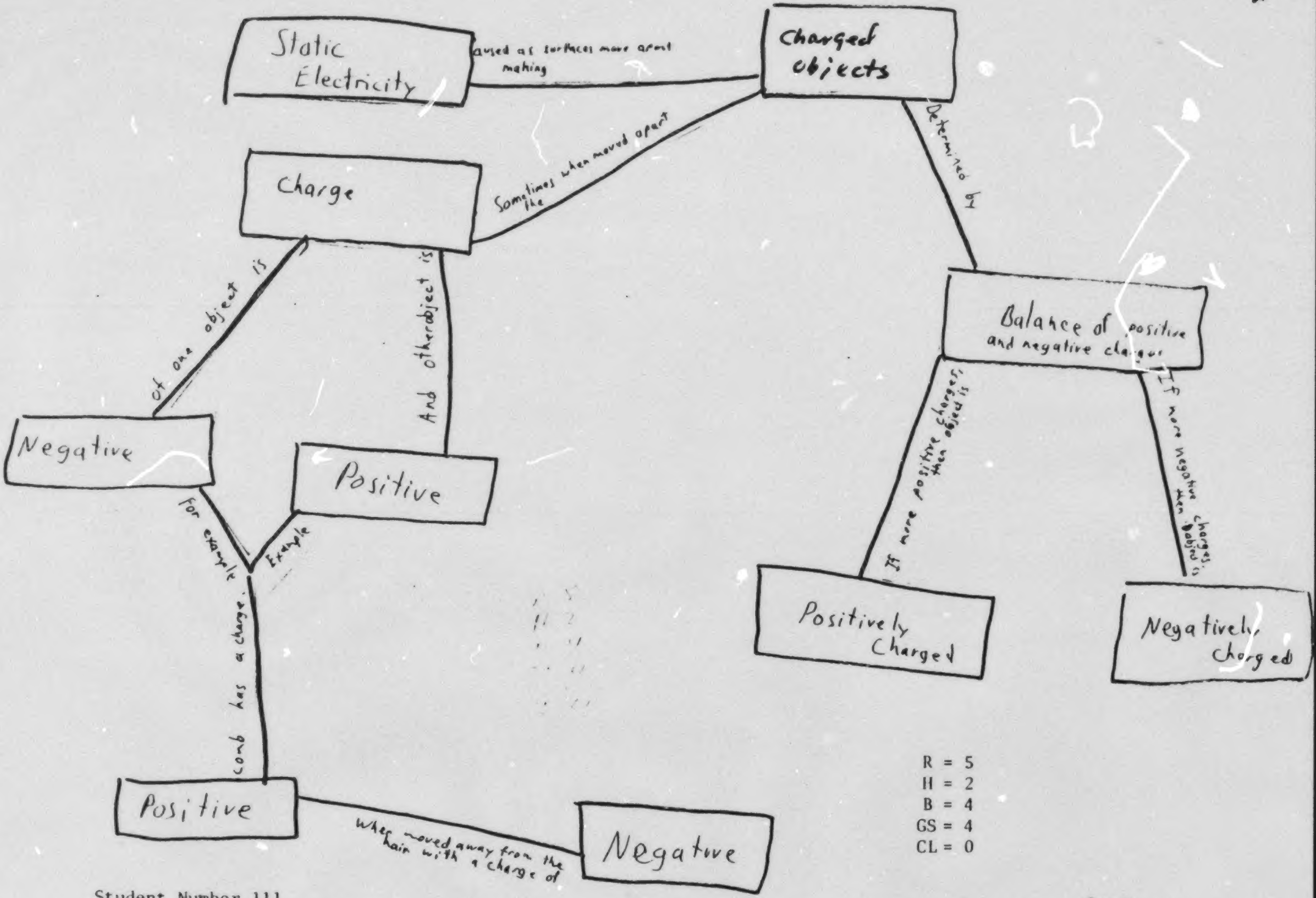
R = 5
H = 2
B = 1
GS = 3
CL = 0

Student Number 200


Cell of a Plant
part of cell
cell membrane
part of plant cell
Cell wall
limits the
allows only certain things to
size of cell
leave and enter cell
part of cell
nucleus
part of cell
Cytoplasm
gives
shape
Contains
genetic material
Contains in it
vacuoles
Contains in it
mitochondria
Contains in it
Chloroplasts

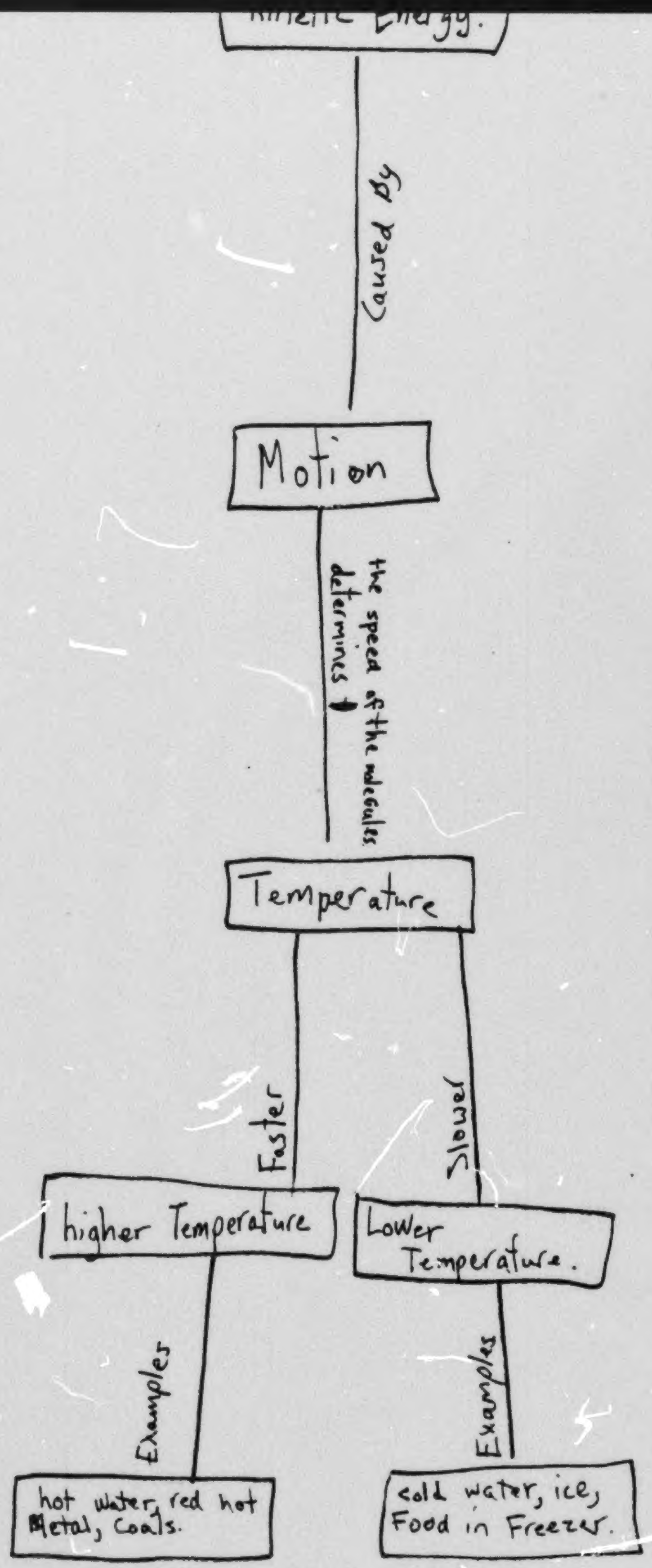
R = 11
H = 2
B = 7
GS = 5
CL = 0

Student Number 239


Static Electricity
aused as surfaces move apart making
Charged objects
Sometimes when moved apart the
Charge
Determined by
Balance of positive and negative charges
Of one object is
And otherobject is
Negative
Positive
If more positive charges then object is
If more negative charges then object is
Positively Charged
Negatively Charged
For example
Example
Comb has a charge.
Positive
When moved away from the hair with a charge of
Negative

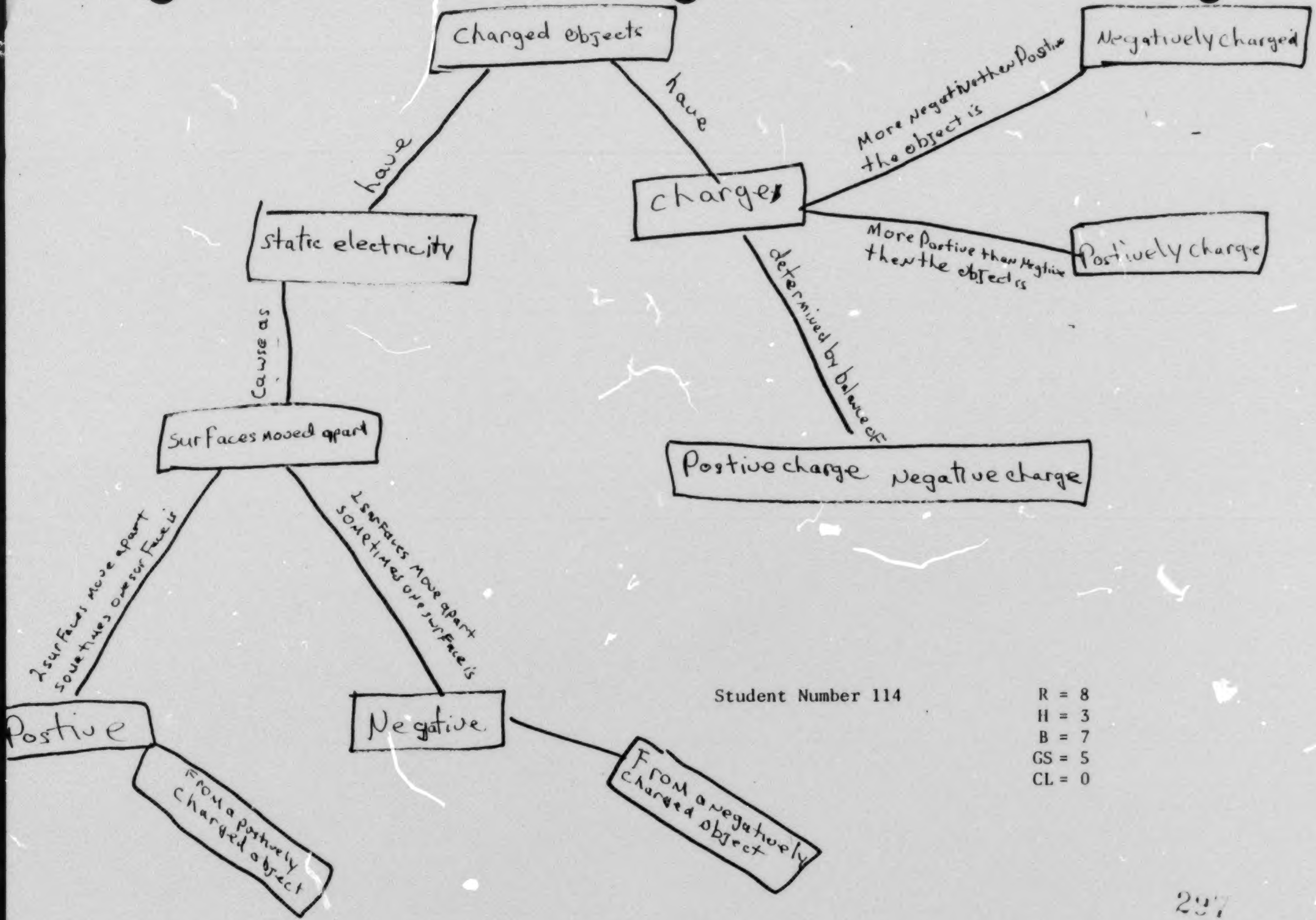
R = 5
H = 2
B = 4
GS = 4
CL = 0

Student Number 111


Kinetic Energy.
Caused By
Motion
the speed of the molecules determines
Temperature
Faster
Slower
higher Temperature
Lower Temperature.
Examples
Examples
hot water, red hot Metal, Coals.
cold water, ice, Food in Freezer.

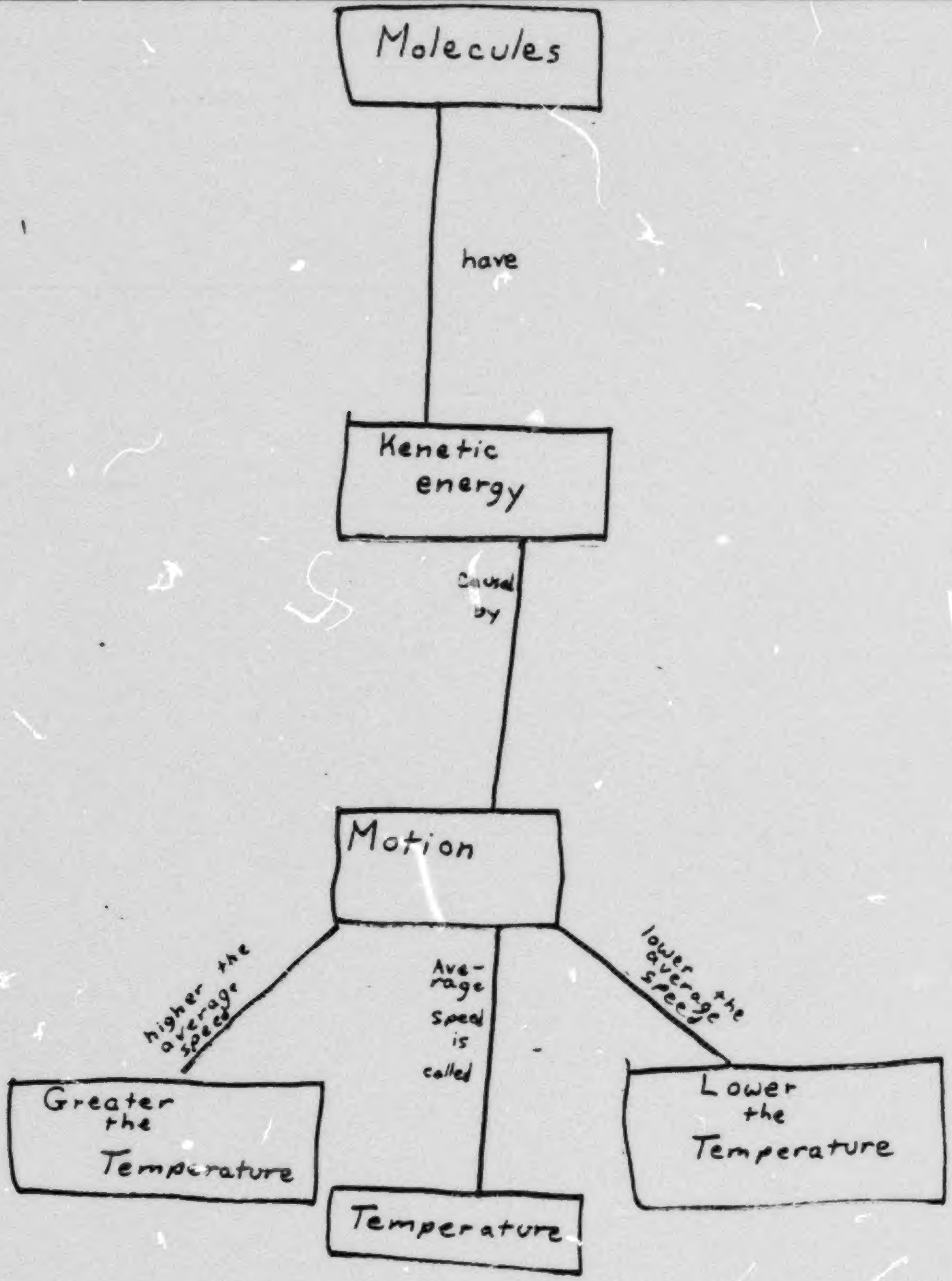
R = 6
H = 3
B = 1
GS = 3
CL = 0

Student Number 112


Charged objects
have
have
static electricity
charges
More Negative then Postive the object is
Negatively charged
More Postive than Negtive then the objects is
Postively charge
Cawse as
determined by balance of
Surfaces moved apart
Postive charge Negative charge
2 surfaces move apart sometimes one surface is
2 surfaces move apart sometimes one surface is
Postive
Negative
From a postively charged object
From a negatively charged object

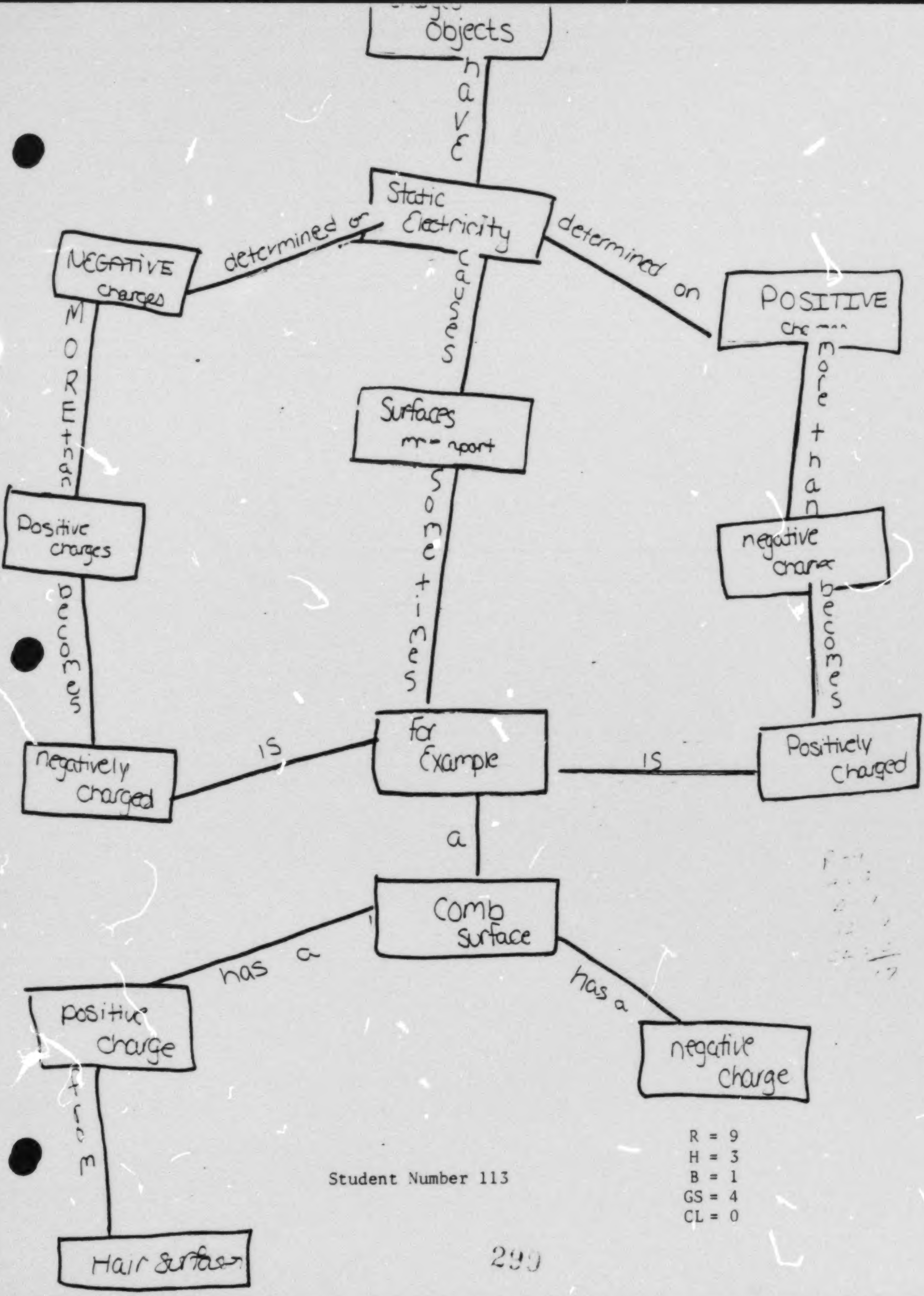
Student Number 114

R = 8
H = 3
B = 7
GS = 5
CL = 0


Molecules
have
Kenetic energy
caused by
Motion
higher the average speed
Average speed is called
lower the average speed
Greater the Temperature
Temperature
Lower the Temperature

R = 5
H = 3
B = 1
GS = 5
CL = 0

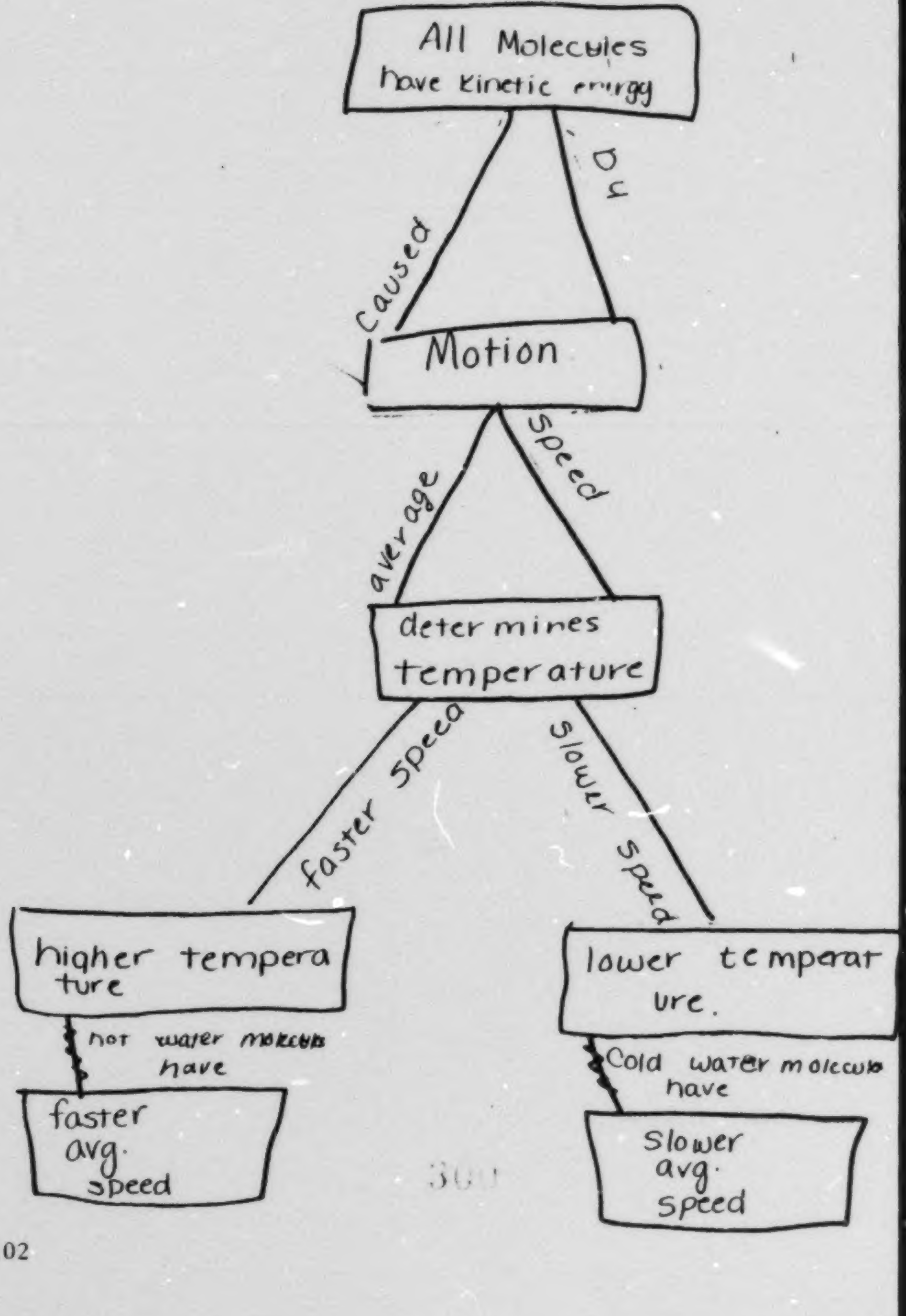
Student Number 115



Objects
have
Static Electricity
determined on
NEGATIVE charges
determined on
POSITIVE
causes
MORE than
more than
Surfaces
Positive charges
negative charge
becomes
sometimes
becomes
negatively charged
IS
for Example
IS
Positively Charged
a
Comb surface
has a
has a
positive charge
negative charge
from
Hair surface

Student Number 113

R = 9
H = 3
B = 1
GS = 4
CL = 0


All Molecules have kinetic energy
caused
by
Motion
average
speed
determines temperature
faster speed
slower speed
higher temperature
lower temperature.
hot water molecules have
Cold water molecules have
faster avg. speed
Slower avg. speed

R = 4
H = 3
B = 0
GS = 5
CL = 0

Student Number 102

INTERVIEW FOR CONCEPT MAPPING (B.1)

Student #003 Seventh Grade, T-burg JHS October 10, 1979

Doug Larison - Interviewer

(T-I-3)

- I'M DOUG LARISON, I'M FROM CORNELL. WE'RE WORKING ON THE PROJECT ABOUT CONCEPT MAPPING WHICH YOU'VE DONE IN CLASS.
-Yep
-JUST TO MAKE SURE WE'RE TALKING AOBUT THE SAME THINGS, COULD YOU TELL ME WHAT A CONCEPT MAP IS?
-It's a map that you have one main thing (UH-HUM), then you draw lines to add parts about them,...and then you draw more lines that tells about the space (UH-HUM),...and then sometimes you might draw lines that cut across that match different ones from this side (UH-HUM),..match up. We did one about respiration (UH-HUM)...and blue at the base (BLUE IS FOR BASE?), Yep (OK, GOOD),...and beef bullion (BEEF BULLION, TOO, HUH?)
-Yep
-GOOD...WHAT DO YOU USE CONCEPT MAPS FOR?
-To...find things more about 'em. (TO FIND THINGS MORE ABOUT THEM?). Yep.
-WELL, WHAT KIND OF THINGS?
-Well, you could ...sometimes you might want to find what they eat, what animals eat (UH HUM), and maybe they could have something like scales...or just to know what they look like, and...
-UH HUM, GOOD. ... WHEN WOULD YOU USE THE CONCEPT MAP?
-Sometimes in tests maybe.
-ALRIGHT, YOU MEAN AN EXAM LIKE WHAT MRS. DE FRANCO WOULD GIVE YOU?
-Yeah
-OK. ANY OTHER TIME?
-Um...Probably'd be some but I can't think of any right now.
-THAT'S ALL RIGHT ... HOW DO YOU THINK THAT CONCEPT MAPS HELP YOU UNDERSTAND THE MATERIAL BETTER?
-(long pause) ...... IS THAT TOO HARD A QUESTION FOR YOU?
-Yes, I'm not sure about it.
-OK. SOME OF THE STUFF I'M GOING TO HAVE YOU DO AND WHAT I'M ASKING RIGHT NOW (yeah) YOU SHOULD UNDERSTAND. THIS IS JUST FOR THE PROJECT THAT WE'RE DOING. OK. THIS IS NOT GOING TO AFFECT YOUR GRADE IN ANY WAY, (ok) OK, AND IF IT'S ALL RIGHT WITH YOU, WE MAY LET MRS. DE FRANCO HEAR THE INTERVIEW SO SHE KNOWS WHERE YOU ARE WITH THE CONCEPT MAPPING. IS THAT OK?
-Uh-hum.
-OK. GOOD. COULD YOU GIVE ME YOUR NAME AGAIN JUST SO WE HAVE IT FOR THE TAPE.
-David Andrews.
-OK. I'M GOING TO GIVE YOU THIS PARAGRAPH TO READ (uh-hum), OK?. (uh-hum), AND TAKE YOUR TIME; YOU MAY WANT TO READ IT MORE THAN ONCE. (ok), SO YOU CAN GET ALL THE IDEAS IN IT, AND WHAT I'M GOING TO HAVE YOU DO IS, I WOULD LIKE YOU TO WRITE ALL THE CONCEPTS -- OK?
-uh hum.
-AND AS YOU FIND THEM IN THIS PARAGRAPH, JUST WRITE ONE ON EACH LITTLE SLIP OF PAPER. THERE'S LOTS OF THEM THERE. OK? YOU MAY WANT TO READ IT THRU FIRST AND THEN KIND OF WRITE IT DOWN, OK?
-Yep. (Pause while David reads the paragraph and writes on the slips---2minutes)
--IS THAT IT?
-Yep
-OK. NOW IS THERE ANYTHING IN THE PARAGRAPH THAT YOU READ THAT YOU DIDN'T UNDERSTAND?
-No.
-NO, YOU'RE SURE?
-uh-hum.
-OK. COULD YOU TAKE OUT THE CONCEPTS THAT YOU WROTE (yeah), AND YOU'VE DONE CONCEPT MAPS BEFORE?(yes). COULD YOU USE THESE YELLOW SLIPS OF PAPER
-and lines?
-AND KIND OF SET IT UP THE WAY YOU WOULD A CONCEPT MAP.

-(-pause while David sets up his concept map ---1 minute 55 seconds).....
-GOOD ... YOU'RE SURE THAT'S HOW YOU WANT IT?
-Uh-Hum.
-OK. NOW FIRST I'D LIKE TO JUST KIND OF IDENTIFY WHAT YOU'VE DONE FOR THE TAPE RECORDING SO THAT WE CAN REMEMBER IT AT A LATER TIME. - YOU PUT ENERGY ON THE TOP HERE AND YOU CONNECTED THAT TO PLANTS AND ANIMALS. NOW WHY ARE THE ANIMALS CONNECTED TO THE ENERGY?
-Well, animals produce energy (UH HUM), plants produce energy (UH HUM),
- AND DO THE ANIMALS ALSO HAVE, WHAT IS THIS?
-Reproduction
-OK. HOW, WHY IS REPRODUCTION IN THERE?
-Well, to keep 'em growing, to have new babies and stuff.
-I SEE, I SEE,
-I connected those two because all of the four go together. (OK) That's why I connected all those.
-ALL 4,--YOU MEAN REPRODUCTION, ANIMALS, PLANTS AND RESPIRATION?
-uh-hum.
-THAT GOES TOGETHER?
-uh hum.
-HOW DOES THE GROWTH AFTER RESPIRATION? HOW DOES THAT WORK?
-um (-long pause)
-OK, uh YOU PUT TRANSPORTATION AFTER REPRODUCTION (yeah) ON THE OTHER SIDE,
-Yes
-HOW DOES THAT WORK? (-long pause by student)
-Well, maybe I should have switched them around. It would be easier...
-WHAT, WHAT, IF YOU SWITCHED THE GROWTH FROM THE TRANSPORTATION?
-No - here.
-LIKE THAT?
-Yeah.
-OK. NOW HOW DOES THAT CLEAR THINGS UP?
-I'm not sure about that one yet, but when they reproduct, they have to grow more to reproduct more.
-OK. TO REPRODUCE MORE, (yeah) THERE'S GROWTH THERE
-OK, THEN I SEE YOU ALSO HAVE A CONNECTION TO LOCOMOTION. DO YOU UNDERSTAND THAT WORD, LOCOMOTION?
Somewhat.
-OK. YOU KNOW WHAT A LOCOMOTIVE IS?
-Yeah
-A TRAIN
-Yeah
-AND LOCOMOTION JUST REFERS TO THE MOVEMENT OF THINGS. WHY IS LOCOMOTION PUT WITH ANIMALS?
-Cause they have four legs..and they run..and walk..and
-GOOD, GOOD, GOOD.
-YOU ALSO CONNECTED both ANIMALS AND PLANTS WITH ORGANISMS. WHY IS THAT?
-Because plants & animals are organisms.
-GOOD. GOOD. ONE MORE? (-long pause by student)
-I DIDN'T MEAN TO CUT YOU OFF. THAT'S WHY I -- DO YOU WANT TO SAY ANYTHING MORE ABOUT THEM? OR IS THAT IT?
-That's it, I forgot the other part.
-GOOD. THAT'S ALL.
-I just read it a little while ago.
-OK. THIS WAS KIND OF RELATED TO IT.
-Yeah.

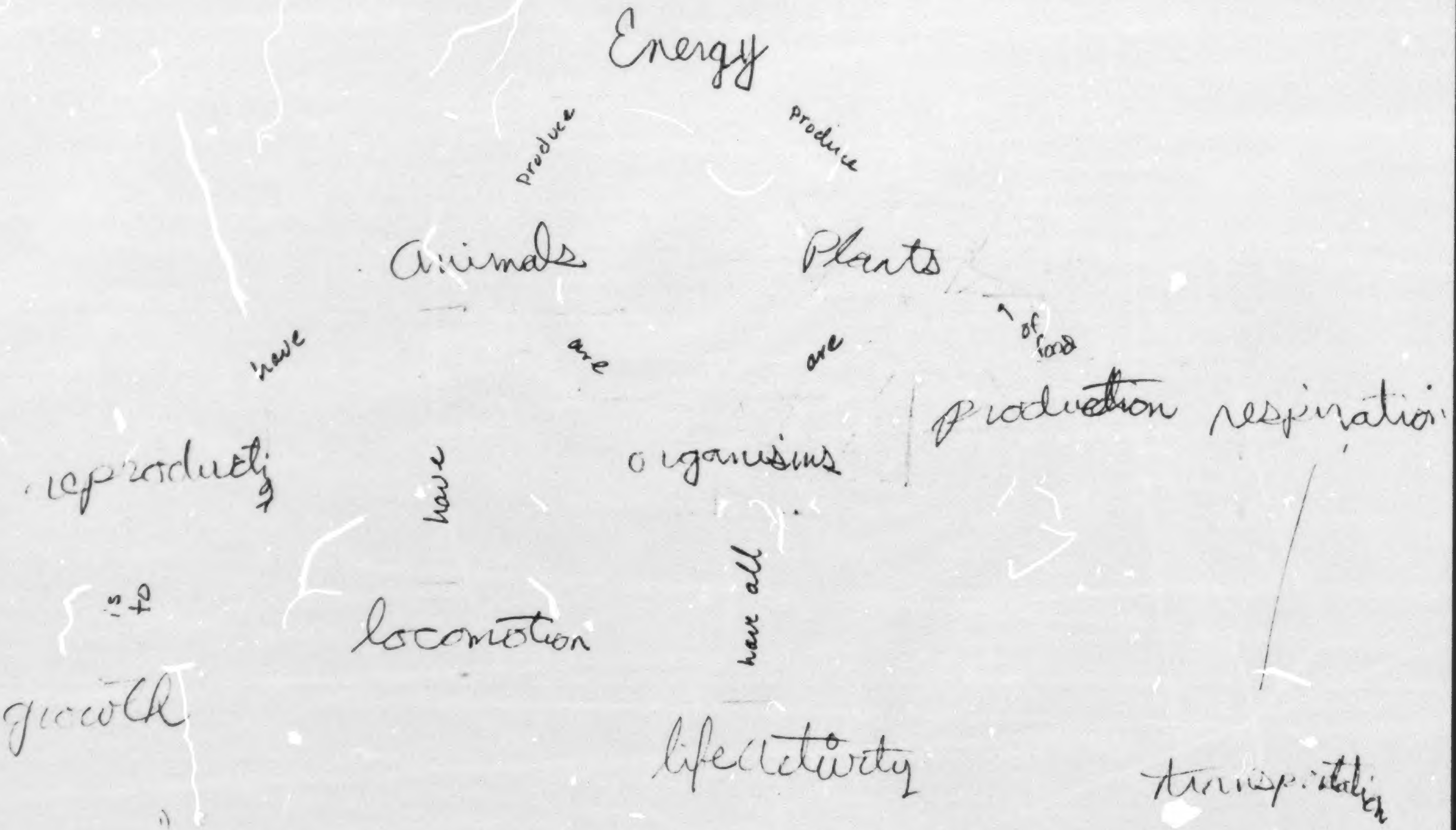
-THIS IS "LIFE ACTIVITY?"
-AND THAT'S RELATED TO ORGANISMS.
-uh hum.
-HOW SO?
-All organisms, plants and animals, have all life activities. Animals will die, then before they die they'll have their life activity.
-GOOD, GOOD.
-AND THEN THIS IS PRODUCTION? FOR PLANTS, RIGHT? HOW'S THAT? HOW DO THOSE WORK TOGETHER?
-(long pause).... Well, the production of food, and they use the -- they product food....., yes, they can product food.
-PLANTS...WHAT?
- , its a production of food.
-I SEE. PLANTS ... OK.
-DO YOU HAVE ANY QUESTIONS? DOES THIS, DOES THIS FOLLOW THE RULES OF CONCEPT MAPS AS YOU KNOW THEM?
-Yeah.
-OK. COULD YOU TELL ME THE RULES OF CONCEPT MAPPING YOU USED TO DO THIS?
-Well, you use it to relate to things (OK), the relation of them (UH HUM), (-long pause).
-ANYTHING ELSE?
-(-long pause)....... They all have, they all do the same things.
-WHAT? I DON'T KNOW WHAT "THEY ALL DO THE SAME THINGS" MEANS. WHAT DO YOU MEAN?
-They all have respiration, and they all have reproduction, and the ones that don't reproduct are..get extinct.
-I SEE ... OK, DO YOU HAVE ANY QUESTIONS FOR ME?
-No.
-OK, THANK YOU FOR TALKING TO ME, OK?
-ok.

elapsed time = 12 minutes

Time to read paragraph = 2 minutes

Time to construct map = 1 minute, 55 seconds

Time for entire interview = 12 minutes


Energy
produce
produce
Animals
Plants
have
are
are
of food
production
respiration
reproducting
have
organisms
is to
have all
locomotion
growth
lifeactivity
transpitation

1)
2) 1
3) 3
4) 1+3+4
5)
1

15/23

[illegible] 1-/79

Student Number - #130

January 16, 1980
Vestal

G. T. J.
Tape Code V-I-9

Uh huh (affirmative)

AND WHAT'S YOUR LAST NAME?

(she then spells it out)

O.K. I'VE GOT TO PUT ALL THIS INFORMATION DOWN. JANUARY 16, 1980, YOU'RE AN EIGHTH GRADER. WE KNOW THAT, BUT I JUST WANT TO....IN VESTAL, AND THAT'S ME. O.K.? GOOD. ALL RIGHT. AS I SAID, WE ARE HERE IN CONNECTION WITH THE CONCEPT MAPPING THAT YOU WERE DOING IN CLASS. THAT'S WHAT WE'RE GOING TO ASK YOU TO DO TODAY, MAKE A CONCEPT MAP. WHAT YOU DO HERE TODAY IS FOR OUR PURPOSES ONLY. ALL RIGHT? IT'S NOT GOING TO AFFECT YOUR MARK IN ANY WAY...IN SCIENCE. O.K.? MR. DECATUR MAY WANT TO SEE THE MAP BECAUSE HE'S KIND OF CURIOUS .... KIND OF CURIOUS ABOUT WHAT'S BEEN GOING ON, STUFF LIKE THAT. DO YOU HAVE ANY OBJECTIONS TO HIM SEEING IT?

Uh uh (negative)

O.K. MOST PEOPLE DON'T. O.K. WE GOT THAT. JUST SO WE THINK WE'RE TALKING ABOUT THE SAME THING, WHAT DO YOU THINK A CONCEPT MAP IS? HOW WOULD YOU DESCRIBE IT?

Well, it's like if you have a paragraph. You can make it like into a diagram, and it's easier to understand. Cause you don't have to read so much.

UH HUH. MAKES IT EASIER THEN? IF YOU HAD A GIRLFRIEND OUT IN CHICAGO CALLING, YOU KNOW, TO FIND OUT WHAT'S GOING ON AND HOW YOU'RE DOING AND YOU'RE TALKING ABOUT CONCEPT MAPS AND SHE ASKS YOU, "WHAT DOES A CONCEPT MAP LOOK LIKE?" HOW WOULD YOU DESCRIBE IT?

It's like, um, it branches out — you'd have a general topic on top and then you'd put, like, a line going down from each one, and it has, like, specific things, and keeps getting down to most specific thing that there is.

I SEE. THOSE LINES...WHAT DO THOSE LINES DO?

Like, they're fill ins for words and stuff, like, if you have a plant and you want to put it's called, you stick it on the line.

UH HUH. ALL RIGHT. GOOD! I THINK WE HAVE AN IDEA ... HAS IT HELPED YOU ANY?

Uh huh (affirmative)

YOU LIKE CONCEPT MAPPING?

Yeah.

IS IT EASIER THAN NOTE TAKING?

Uh huh (affirmative)

HAVE YOU USED IT TO STUDY FOR A TEST?

Yeah.

DID YOU GET A BETTER MARK?

Well, we only took about two tests, but I got a better mark this time.

GOOD! VERY GOOD! O.K. GOOD. THAT'S WHAT WE'RE INTERESTED IN ... TO SEE IF WE CAN DO THAT. O.K. WHAT I'M GOING TO DO IS I'M GOING TO GIVE YOU A PARAGRAPH TO READ AND IT'S KIND OF SHORT, SOME ARE WORDS THAT YOU'VE HAD ALREADY, YOU KNOW, SO IT'S NOTHING BRAND NEW, AND WHAT I'M GOING TO ASK YOU TO DO IS READ THE PARAGRAPH AND THEN IDENTIFY THE CONCEPTS IN THERE. O.K.? AND YOU WILL BE ABLE TO WRITE THESE CONCEPTS DOWN ON THESE LITTLE SHEETS OF PAPER. O.K.? NOW, WE USE THESE LINES ... THESE YELLOW PIECES OF PAPER TO REPRESENT THE LINES. WE DO THIS SO WE CAN MOVE IT AROUND INSTEAD OF WRITING IT OUT AND CROSSING IT OUT. O.K.? AND YOU CAN WRITE ON THESE...THE CONCEPTS ON THESE AND YOU CAN WRITE ON WHAT EVER CONNECTION YOU WANT TO MAKE THERE. O.K.? SO, IF YOU'LL JUST READ THIS TO YOURSELF, YOU MAY WANT TO READ IT MORE THAN ONCE. I WON'T TAKE IT AWAY FROM YOU. WE CAN LEAVE IT OVER THERE TO REFER TO, O.K.?

(Pause for 16 seconds while reads paragraph.)

o.k., got it.

IS THERE ANYTHING IN THE PARAGRAPH YOU DON'T UNDERSTAND? ANY CONCEPT...ANY WORDS? NO? LOOK PRETTY FAMILIAR? THAT'S THE WAY WE WANTED IT. O.K. NOW, IF YOU WOULD, YOU CAN.....NOW, AND START WRITING OUT THE CONCEPTS...THE CONCEPTS ON THOSE PAPERS....

(Pause for 15 seconds while writes concepts.)

Is it all right if I stick them here?

YOU CAN
SURE. WHATEVER YOU WANT. /MAKE THE MAP AS YOU GO ALONG.

(Pause for 1 minute, 13 seconds)

Oh, boy.

(LAUGHTER) THAT'S THE WORST PART. THESE THINGS....FALL APART A LITTLE BIT. ...THERE WE GO. NEATNESS DOESN'T COUNT, SO DON'T WORRY ABOUT THAT. O.K.?

(Pause for 2 minutes, 44 seconds)

I guess I'm finished.

O.K. GOOD. VERY GOOD. O.K. YOU'RE NOT STUCK WITH IT. IF YOU WANT TO MAKE ANY CHANGES, ADJUSTMENTS, ADDITIONS, SUBTRACTIONS, MOVE IT AROUND. WHATEVER YOU WANT TO DO, YOU CAN, O.K.?

(Pause for 17 seconds)

I guess that's it.

O.K. FINE. I WANT TO IDENTIFY IT FOR THE TAPE RECORDER, O.K.? ...

Uh huh (affirmative)

SO THAT IT KNOWS. O.K. PUT "MATTER" UP ON TOP CONNECTED TO THE CONCEPT "MOLECULES," AND HAS WRITTEN "HAS" ON THE LINE IN BETWEEN. MOLECULES IS CONNECTED TO "MOTION" AND THE WORDS "ARE IN" CONNECT THOSE TWO CONCEPTS. MOTION IS CONNECTED TO "TEMPERATURE" WITH THE WORD "DETERMINES" ON THE LINE. TEMPERATURE HAS TWO LINES COMING OFF IT. ON THE LEFT CONNECTED TO "FASTER MOVING" AND THE WORD "IF" BETWEEN IT. THEN FASTER MOVING CONNECTED TO THE CONCEPT "HIGHER TEMPERATURE" WITH THE WORD "HAS" IN BETWEEN. ON THE RIGHT HAND SIDE OF TEMPERATURE THE WORD, EXCUSE ME, TEMPERATURE IS CONNECTED TO THE CONCEPT "SLOWER MOVING" WITH THE WORD "IF" IN BETWEEN, AND THAT'S CONNECTED TO "LOWER TEMPERATURE" WITH THE WORD "HAS" IN BETWEEN. O.K.? ALL RIGHT. WHY DID YOU CONNECT THESE TWO UP HERE?

Because all matter is made of molecules.

UH HUH. WHY DID YOU CONNECT THESE TWO?

Because molecules are in constant motion.

I SEE. AND, WHY DID YOU CONNECT THESE TWO. IT'S PRETTY EASY...IT'S PRETTY DEFINITE THE WAY YOU HAVE IT.

Well, the motion determines the temperature.

IS THAT WHAT IT IS? THE MOTION DETERMINES THE TEMPERATURE? OR DOES THE TEMPERATURE DETERMINE THE MOTION?

The motion determines the temperature, cause if they're faster moving, it's got a higher temperature.

UH HUH I SEE. O.K. FINE. BOY! YOU JUST WANT TO ZIP RIGHT THROUGH THIS! SO YOU WON'T HAVE THAT MANY QUESTIONS ON IT. WOULD YOU USE THIS FOR FOR SOCIAL STUDIES OR MATH OR SOMETHING. COULD YOU USE A CONCEPT MAP FOR THOSE.

Yeah, for social studies. I don't know about math.

HAVE YOU GIVEN IT ANY THOUGHT?

Yeah, I'd use it for social studies.

YEAH? OH! IS IT SIMPLER TO LOOK AT SOCIAL STUDIES? YOU MENTIONED AT THE BEGINNING THAT YOU PUT YOUR MORE GENERAL CONCEPT UP HERE, AND THE MORE SPECIFIC CONCEPTS OUT HERE. IS THAT HOW YOU DID IT HERE? DO YOU THINK?

Yeah, I'm pretty sure.

YOU'RE PRETTY SURE? O.K. GOOD! WELL, I DON'T HAVE ANY MORE QUESTIONS FOR YOU. YOU REALLY ZIPPED RIGHT THROUGH THAT. VERY GOOD. DO YOU HAVE ANY QUESTIONS FOR ME?

No.

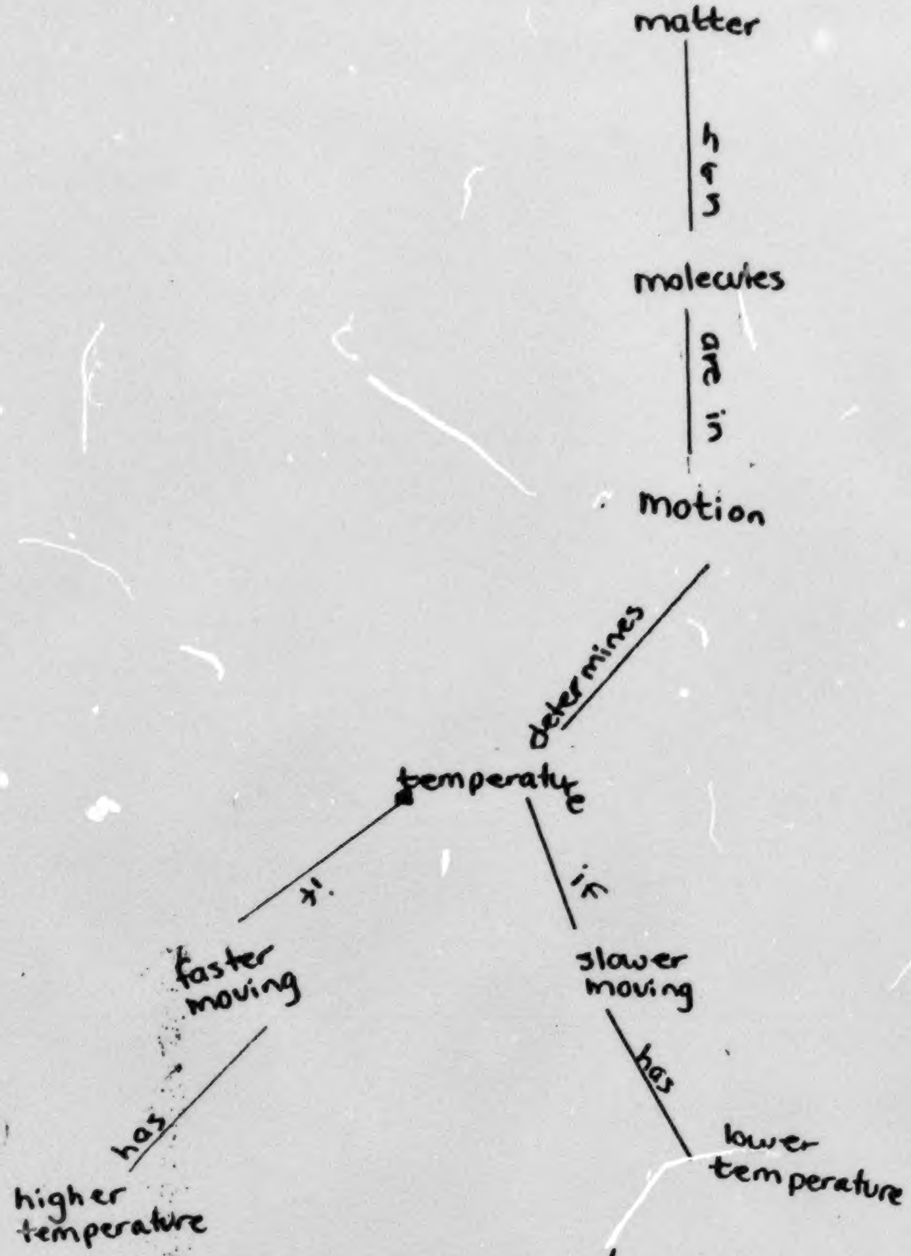
NO? O.K. WAS IT AS BAD AS YOU THOUGHT IS WAS GOING TO BE?

No.

NO? SEE? IT'S NEVER AS BAD AS PEOPLE SAY IT'S GOING TO BE. O.K.!

Time to read paragraph = 16 seconds

Time to construct map = 4 minutes, 29 seconds


matter
has
molecules
are in
motion
determines
temperature
if
if
faster moving
slower moving
has
has
higher temperature
lower temperature

R - 7
H - 5
B 1
5
GS 0
CU
18

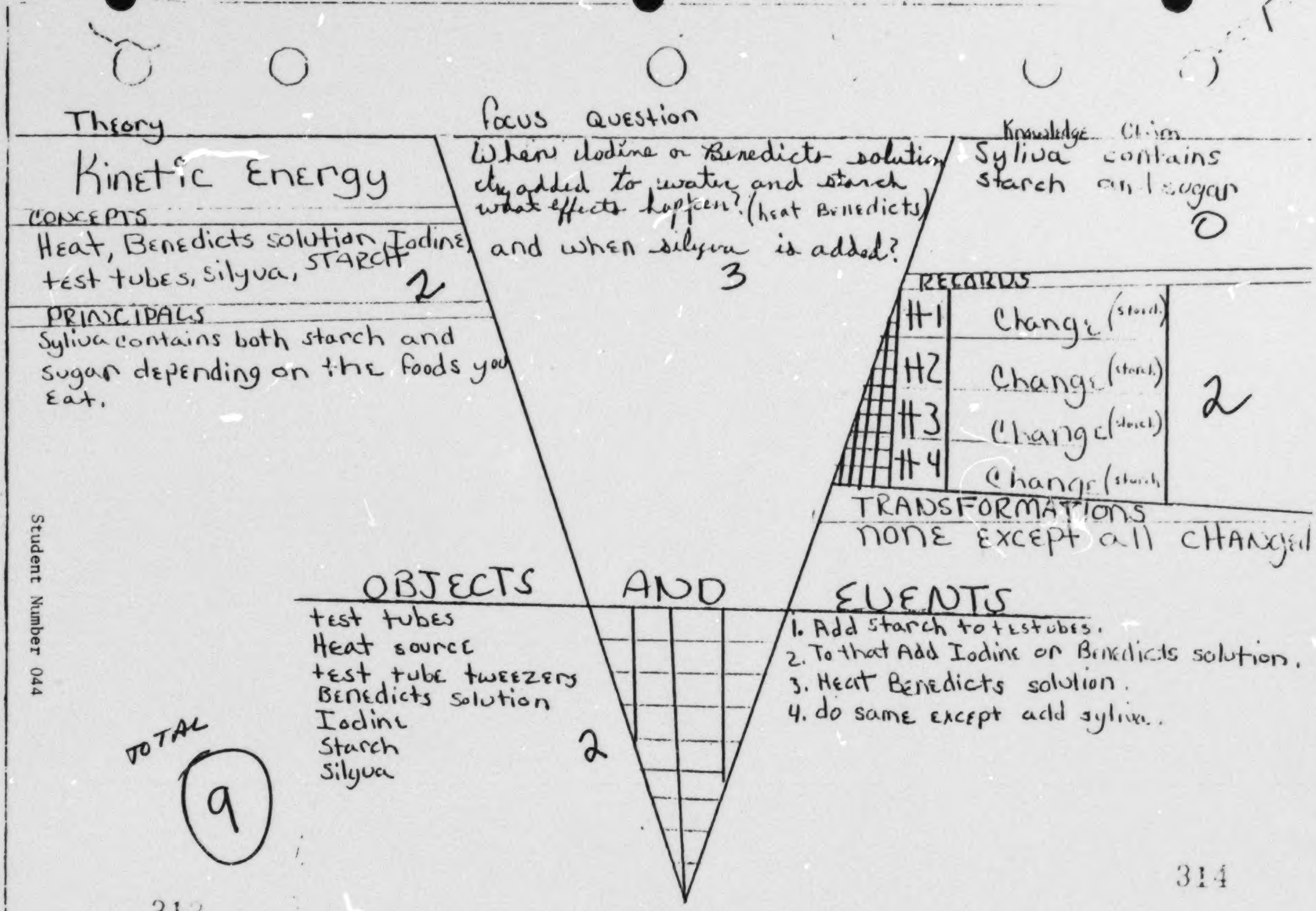
VI-9

JAN 16, 1980 8th Grader Vestal

GTJ

APPENDIX III

Sample laboratory exercises represented on the Knowledge "V" from students in Trumansburg, 1979-1980.



Theory

Kinetic Energy

CONCEPTS

Heat, Benedicts solution Iodine, test tubes, silyva, STARCH

2

PRINCIPALS

Sylivacontains both starch and sugar depending on the foods you Eat.

Focus QUESTION

When iodine or Benedicts solution is added to water and starch what effects happen? (heat Benedicts) and when silyva is added?

3

Knowledge Claim

Syliva contains starch and sugar

0

RECARDS

#1	Change (starch)
#2	Change (starch)
#3	Change (starch)
#4	Change (starch

2

TRANSFORMATIONS

NONE EXCEPT all CHANged

OBJECTS AND EVENTS

test tubes
Heat source
test tube tweezers
Benedicts solution
Iodine
Starch
Silyva

2

1. Add starch to testubes.
2. To that Add Iodine or Benedicts solution.
3. Heat Benedicts solution.
4. do same except add syliva.

TOTAL

9

Student Number 044

Student Number 051

Theory

Kinetic Energy

Principles

Focus Question

What effect does saliva have on starch?

3

Knowledge Claim

0

TOTAL

11

Records

Testube 1 Turned black
Testube 2 Stayed blue
Testube 3 Turned green
Testube 4 Turned black

4

2

Concepts

Starch
Sugar
Saliva

Transformations

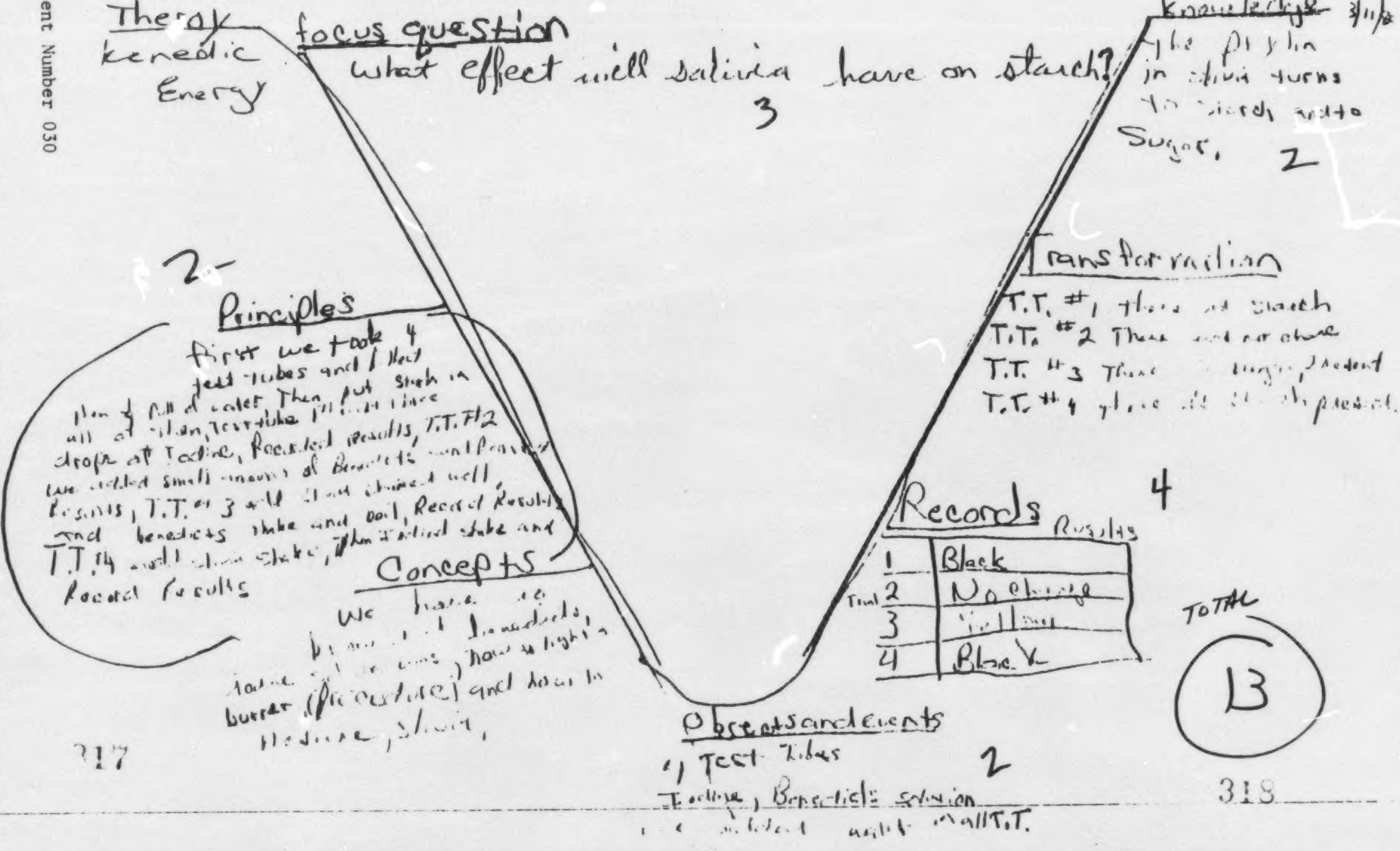
Testube 1	Had starch
2	no sugar
3	Had sugar
4	Had starch

Objects + Events

① four testube with 1/4 water
2 ② Starch in each
③ few drops Iodine in T.T. one
④ benedicts in T.T. two and boil
⑤ Saliva and benedicts in T.T. three boil
⑥ Saliva and Iodine T.T. four

Student Number 030

P.S. T.T. means Test Tube



Theroy
kenedic
Energy

focus question
What effect will saliva have on starch?
3

knowledge 3/11/8[illegible]
the ptylin in saliva turns the starch and to Sugar.
2

2-

Principles
first we took 4 test tubes and filled them ½ full of water Then put starch in all of them, Test tube #1 [illegible] three drops of Iodine, Recorded results, T.T. #2 we added small amount of Benedicts and [illegible] well, Results, T.T. #3 add [illegible] [illegible] and benedicts shake and boil, Record Results and T.T. #4 add [illegible] shake, then I added [illegible] shake and Record results

Concepts
We have [illegible] [illegible] [illegible] benedicts, [illegible] [illegible] [illegible], how to light a bunsen burner (procedure) and how to Measure, [illegible],

Transformation
T.T. #1 there [illegible] starch
T.T. #2 There [illegible] no change
T.T. #3 There [illegible] sugar present
T.T. #4 there [illegible] [illegible] present.

4

Records Results

1	Black
Trial 2	No change
3	Yellow
4	Black

Objects and events
1) Test Tubes
Iodine, Benedicts solution
[illegible] [illegible] added [illegible] in all T.T.

2

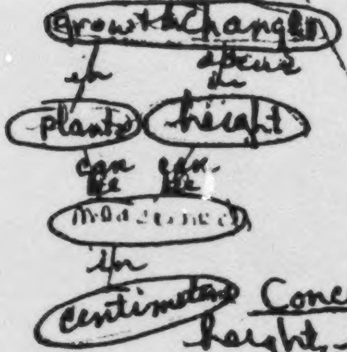
TOTAL
13

focus Question What changes in growth occured in the bean seeds from day to day?

3

Theory
cell theory

Principles


growth changes
in
occurs in
plants
height
can be
can be
measured
in
centimeters

4

Concepts
height, plants, measuring, growth, changes, centimeters

1

Knowledge Claims
The beans seeds gra
taller. They grew slo
in the first 5 days and
more quickly in the last
5 days.

~~4~~ 3

Transformations
Look on page 166 (3rd page;

1 4

Records
Look on page 167 (3rd page)

Objects/Events

1) Build growth chamber + plant bean seeds
2) Measure and record plant height each day
3) Prepare a bar graph of the results

TOTAL 17

3

No Student Number Identified

5.4.80

Student Number 085

Theory

Cell theory

Focus Question

Are yeast cells respiration influenced by temperture?

2

KC

Yes at a certain point through the yeast die.

4

Principles

Yeast cells are influenced by temperterre. We can test yeast cells to see what kind of gas is given off. If we use bromthymal blue if CO_2 is given off it will turn greenish-yellow.

Concepts

Yeast, cell, respiration, temperatures, bromthymol blue, carbon Dixode, influenced, gas

4

Records

	0	1	2
Room	Blue	Light green Blue	light Blue
Hot 2	Dark green	green	green
Cold 3	Dark green	Blue green	Blue green
4	Blue green	Blue green	Blue green

2

Trans

See data

Objects

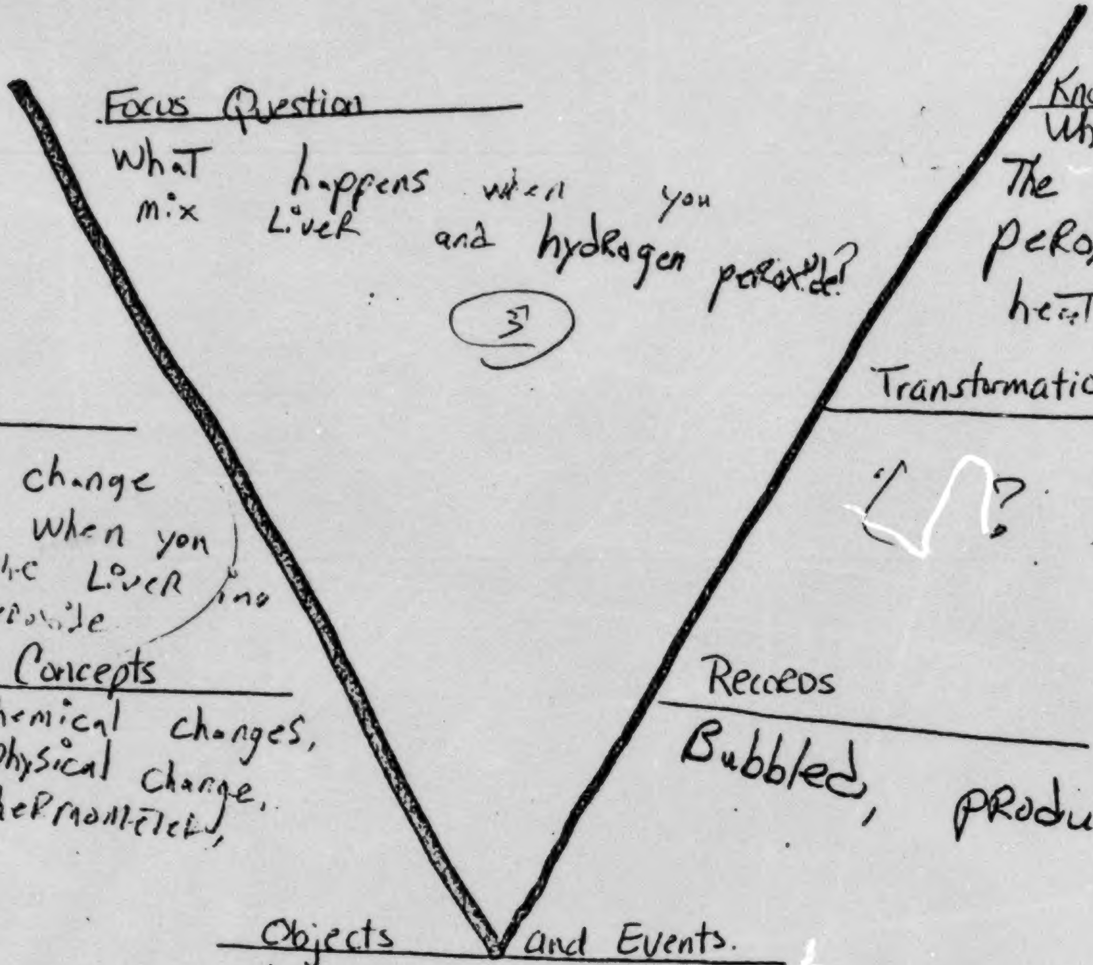
Yeast
Water
Bromthymal blue
test tube rack
4 test tubes
Stopper
Sugar
Medicine dropper

2

Events

TOTAL = 14

9/28/79



Theory

Focus Question

What happens when you mix Liver and hydrogen peroxide?

③

Knowledge Claim

When you add The Liver To The peroxide IT makes heat. Chemical change.

④

Transformations

?

Principles

Chemical change occured when you put The Liver ino The peroxide

Concepts

Chemical changes, physical change, Thermometer,

①

Records

②

Bubbled, produced heat

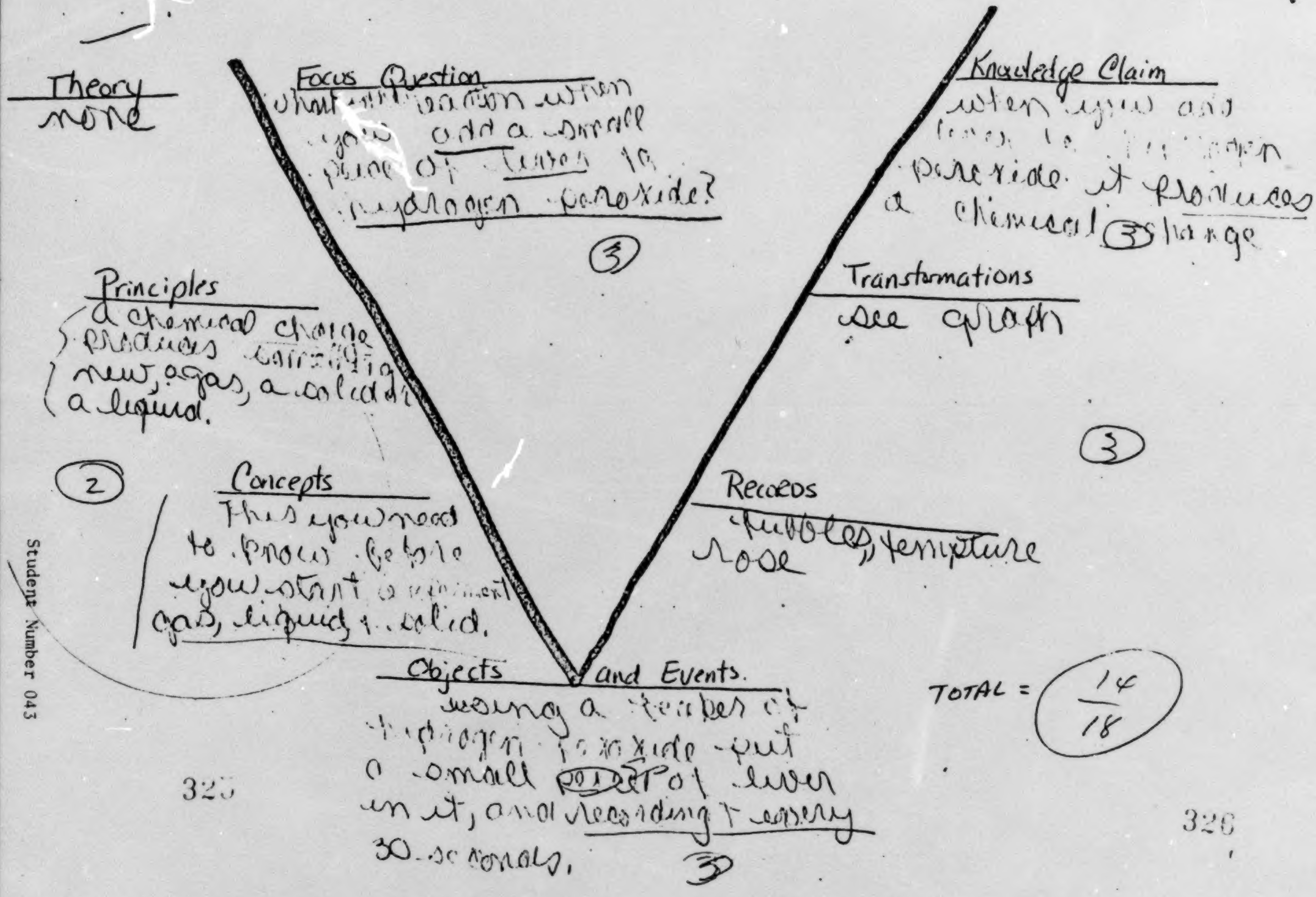
Objects and Events.

Thermometer, Hydrogen peroxide, Liver

①

TOTAL = $\frac{11}{18}$

Student Number 005



Student Number 043

Theory

none

Focus Question

what will reaction when you add a small piece of liver to hydrogen peroxide?

③

Knowledge Claim

when you add liver to hydrogen peroxide. it produces a chemical ③ change

Principles

a chemical change produces something new, a gas, a solid or a liquid.

②

Transformations

see graph

③

Concepts

Things you need to know before you start experiment gas, liquid & solid.

Records

bubbles, tempiture rose

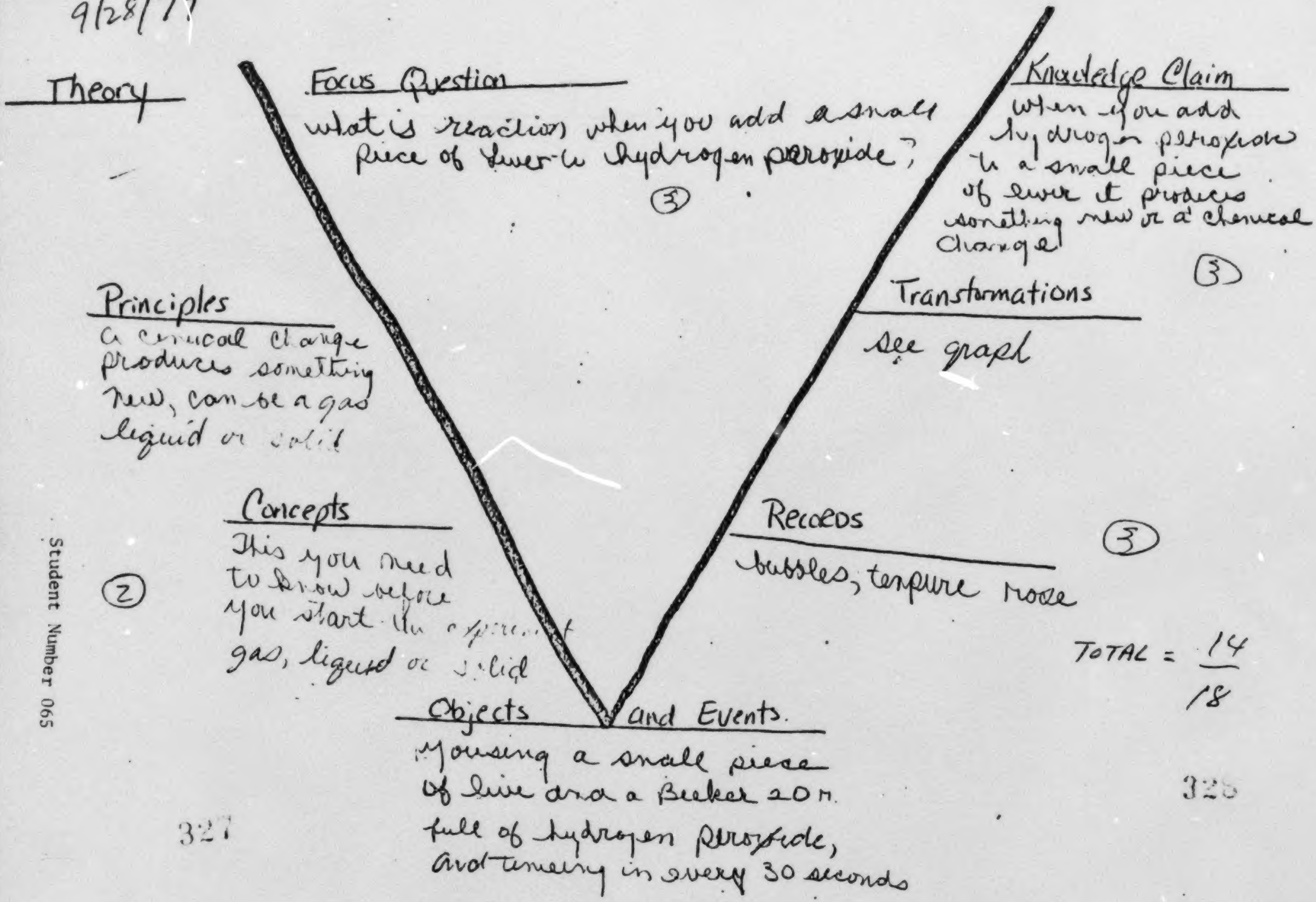
Objects and Events.

using a beaker of hydrogen peroxide put a small piece of liver in it, and recording every 30 seconds.

③

TOTAL = 14/18

9/28/79



Theory

Focus Question

what is reaction when you add a small piece of liver to hydrogen peroxide?

③

Knowledge Claim

When you add hydrogen peroxide to a small piece of liver it produces something new or a chemical change

③

Principles

a chemical change produces something new, can be a gas liquid or solid

Transformations

See graph

Concepts

This you need to know before you start the experiment

gas, liquid or solid

②

Records

bubbles, temperature rose

③

TOTAL = 14/18

Objects and Events.

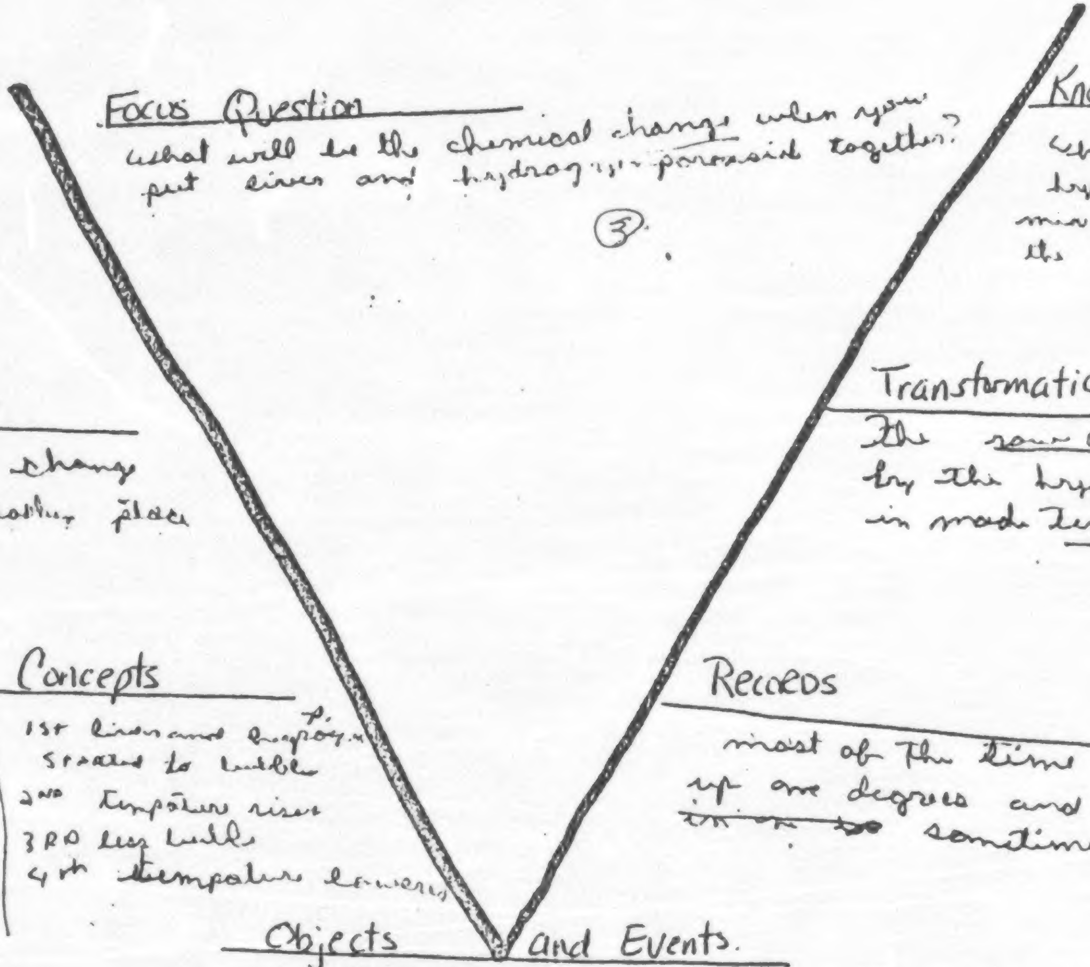
Housing a small piece of liver and a Beaker 20 ml. full of hydrogen peroxide, and timeing in every 30 seconds

③

Student Number 065

9/28/79

Theory



Focus Question

what will be the chemical change when you put livers and hydrogyn poroxide together?

③

Knowledge Claim

When raw livers and hydrogen poroxide are mix they bubbled and the tempature rose.

②

Principles

a chemical chang would be taking place

Transformations

The raw liver was eaten away by The hydrogyen poroxide and in made Tempature rise.

②

Concepts

1st livers and hydropoxide starts to bubble
2nd tempature rises
3rd less bubbles
4th tempature lowers

⓪

Student Number 002

Records

most of The time the tempature went up one degrees and it went up 2 degrees ~~in or so~~ sometimes.

Objects and Events.

you had to use raw livers and hydrogen poroxide and put them together, then you had to use a thermometer to watch the tempature every 30 sec.

②

TOTAL = 9/18

323

trial	result	conclusion
# 1	turned black	contains starch
# 2	nothing	–
# 3	turned green	contains sugar
# 4	turned purple	contains starch

4

theory:
kinetic energy

principles:
1. iodine shows that starch is present.
2. benedict's shows that sugar is present

concepts:
starch, sugar, benedict's iodine, saliva

3 **focus question:**
How can we prove saliva changes starch to sugar by using iodine, + benedict's?

3

knowledge claim:
on back of paper

records:

trial	result	conclusion
1	turned black	contains starch
2	–	–
3	turned green	contains sugar
4	turned purple	contains no [illegible]

2

principles:
trial 1 - black - starch
2 - nothing -
3 - green - sugar
4 - purple - starch

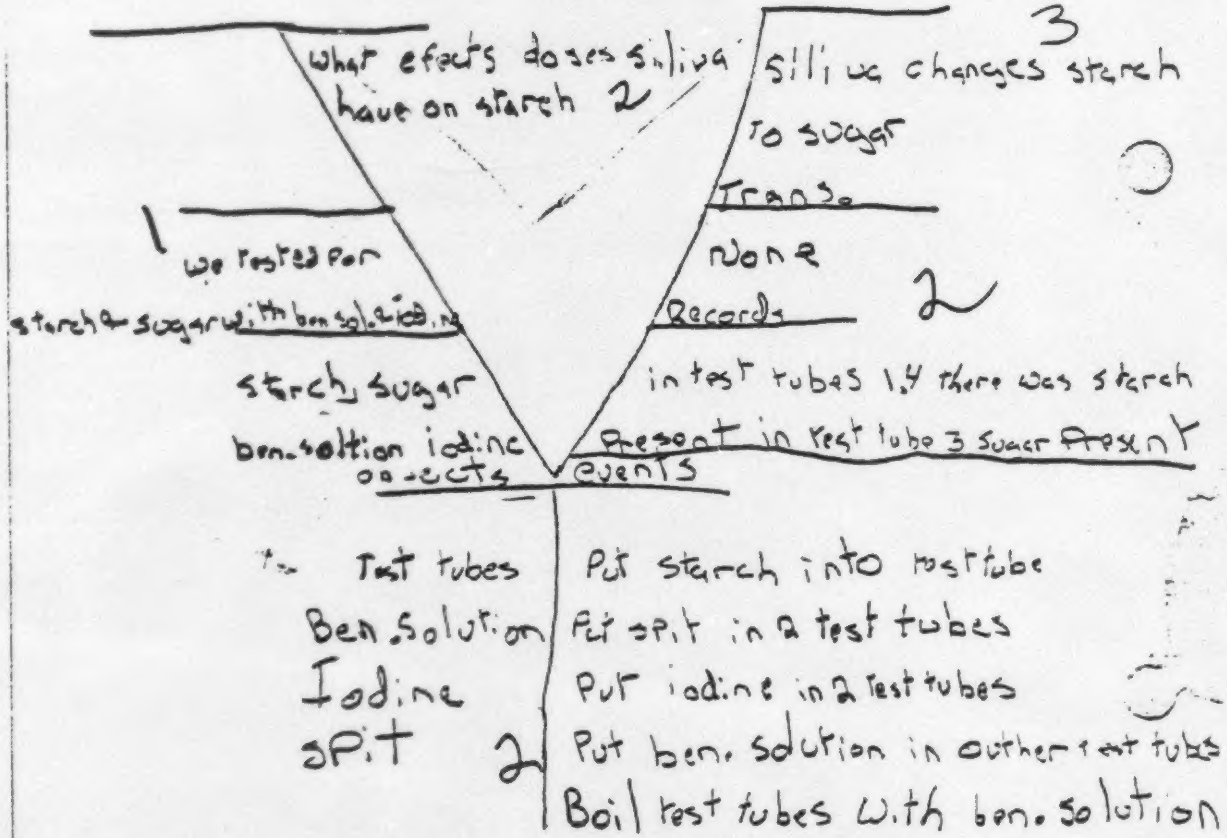
3

objects:
starch
sugar
saliva
iodine
benedict's

events:
① fill test tubes 1/4 full of water and add small amount of starch
② add a little saliva to #1
③ add benedict's + boil to #2
④ #3 - add saliva, benedict's and boil
⑤ #4 - add saliva + iodine.
⑥ record results for all of them

Student Number 068

TOTAL = 15/18



what efects doses siliva have on starch 2

silliva changes starch to sugar 3

Trans.

None

Records 2

in test tubes 1,4 there was starch present in test tube 3 sugar present

1 we tested for starch & sugar with ben sol. & iodine

starch, sugar ben. soltion iodine

objects	events
Test tubes	Put starch into testtube
Ben. Solution	Put spit in 2 test tubes
Iodine	Put iodine in 2 test tubes
spit 2	Put ben. solution in outher test tubes
	Boil test tubes with ben. solution

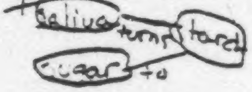
TOTAL = 10

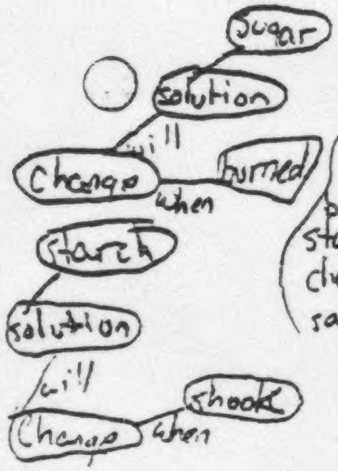
Student Number 009

Theory:

none

principles:


saliva
turns
starch
sugar
to


sugar
solution
will
change
burned
when
starch
solution
will
change
shook
when

concepts:

burn, solution
starch, sugar,
change, results,
saliva

2

Focus Question:

- when adding saliva to starch, does the starch change to sugar?

3

[illegible] claim:

Yes, saliva changes starch to sugar.

3

Transformations:

	#1 starch, iodine	#2 starch [illegible]	#3 starch, saliva, Ben. sol. boil	[illegible]
1	Black			
2		nochange		
3			green-yell	
4				black-bl

4

Records:

#1	black
#2	no change
#3	green-yellow
#4	black-blue

Objects/events:

3

1. four tt's, 1/4 fill w/ H_2O
2. add sm. amt. of starch to each tt
3. #1 add few drops iodine
4. shake ~~tt~~ and record results
5. #2 add sm. amt. of Ben. sol., boil
6. record results
7. #3 add some saliva, shake well
8. #3 add Ben., boil
9. record results
10. #4 add saliva, shake well, add iodine
11. record results

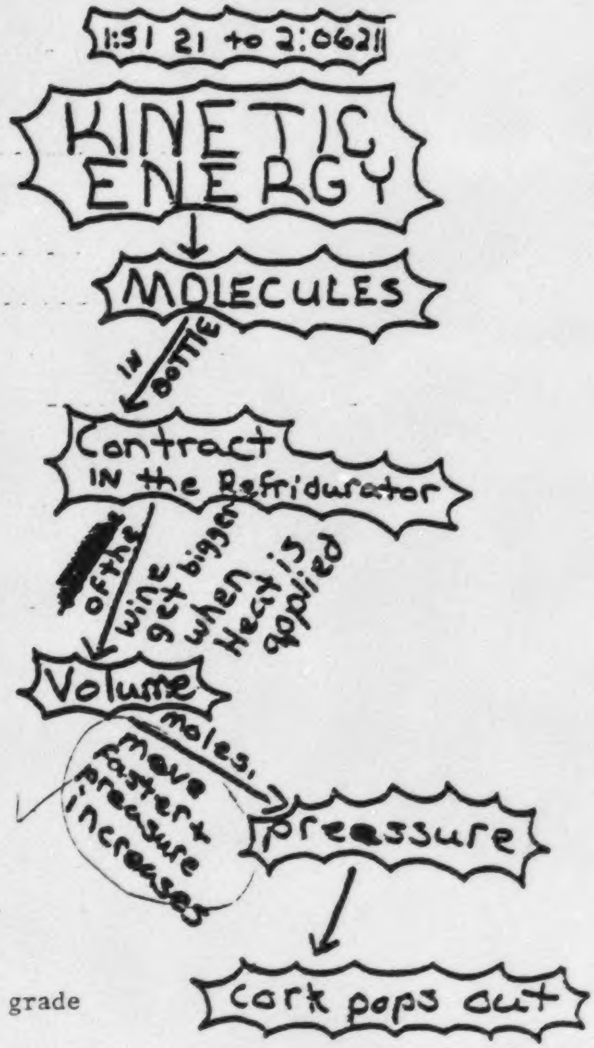
TOTAL = 15

Student Number 067

APPENDIX IV

Samples of students' explanations and concept maps for the "Winebottle" and "Electricity" examples of conceptual questions.

While the wine bottle is in the refriderator the cool air makes the molecules slow down. The~~y~~ sudden warmth when taken out of the cold make them move very fast. the pressure builds up and the cork pops out.

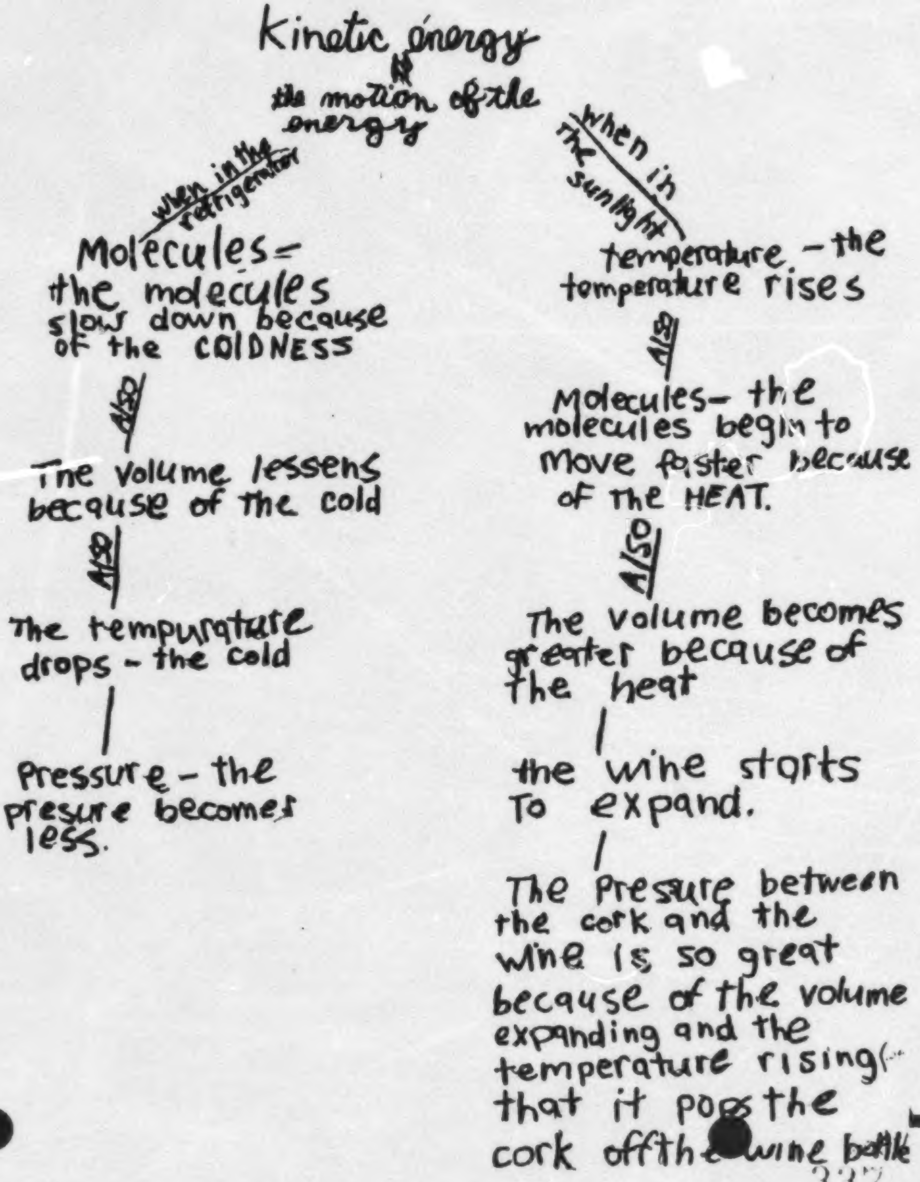

1:51 21 to 2:06 21
KINETIC ENERGY
MOLECULES
IN BOTTLE
Contract IN the Refridurator
of the wine get bigger when Heat is applied
Volume
moles, move faster & preasure increases
preassure
cork pops out

Student Number 104, Vestal-8th grade

April, 1980

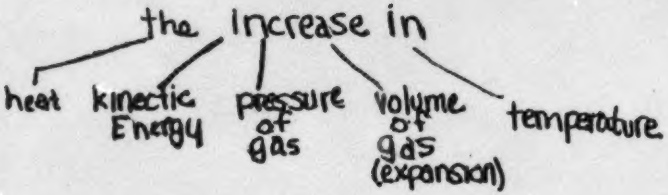
When the wine was in the refrigerator, the molecules began to slow down. The volume began to lessen. The tempurature dropped. The pressure becamel less. All because the tempurature dropped and it became cold.

In the sunlight. The temperature rose. The molecules began to move faster! The volume became greater. The wine starts to expand. All because of the heat gained. But the presure between the cork and the wine is so great because of the/ volume expanding and the temperature rising (etc), That it popped the cork off the bottle.

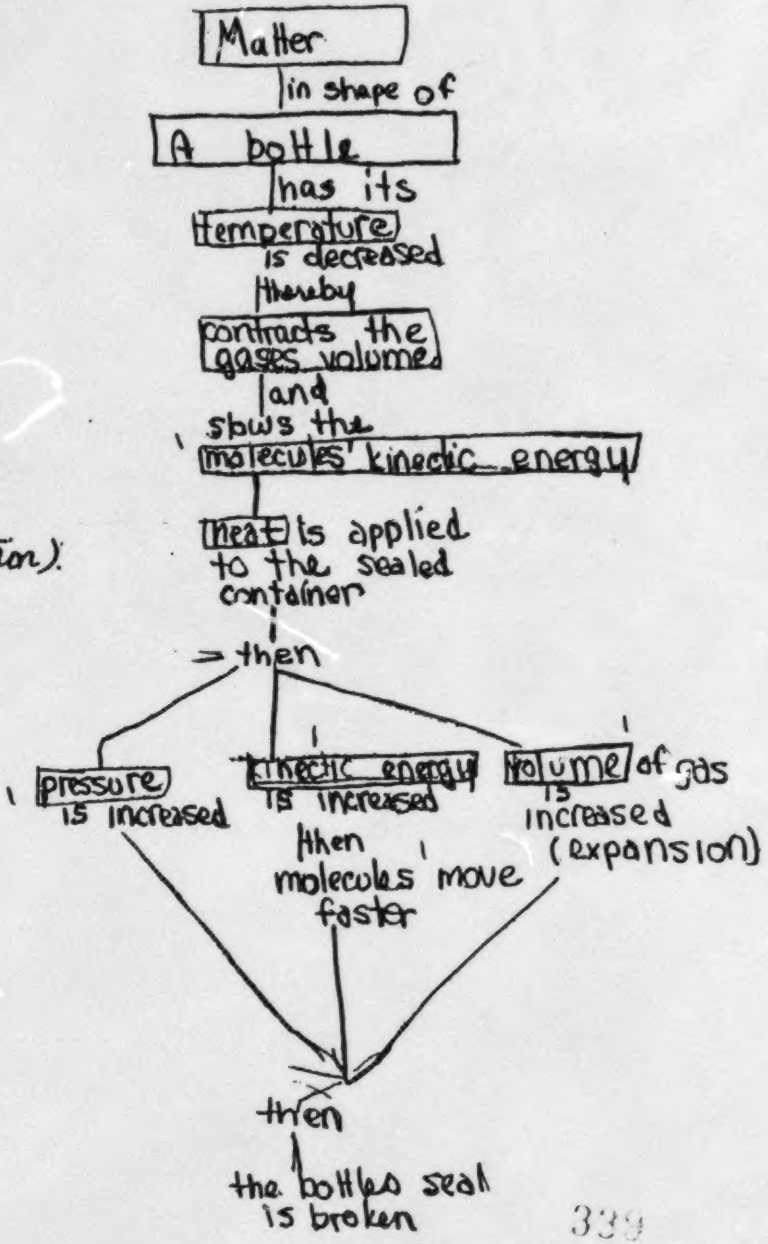

Kinetic energy
is
the motion of the energy
when in the refrigerator
when in the sunlight
Molecules- the molecules slows down because of the COLDNESS
Also
The volume lessens because of the cold
Also
The tempurature drops - the cold
Pressure - the presure becomes less.
temperature - the temperature rises
Also
Molecules- the molecules begin to move faster because of the HEAT.
Also
The volume becomes greater because of the heat
the wine starts to expand.
The Presure between the cork and the wine is so great because of the volume expanding and the temperature rising (…
that it pops the cork off the wine bottle

Student Number 139, Vestal-8th grade

April, 1980


the increase in
heat
kinectic Energy
pressure of gas
volume of gas (expansion)
temperature

Matter, in shape of a bottle, has it's temperature decreased. This brings about a decrease of the volume of gases contained within, a decrease of molecular' kinectic energy a decrease in the gas' pressure(contraction). The sealed container has heat applied. This starts an increase in heat, kinetic' energy, pressure, expansion, volume of gas and temperature. The gas expands, pushing outward with greater force than before, so it must take up more space. This gas has to break the seal so that the gas within may expand. It does so, breaking the seal.

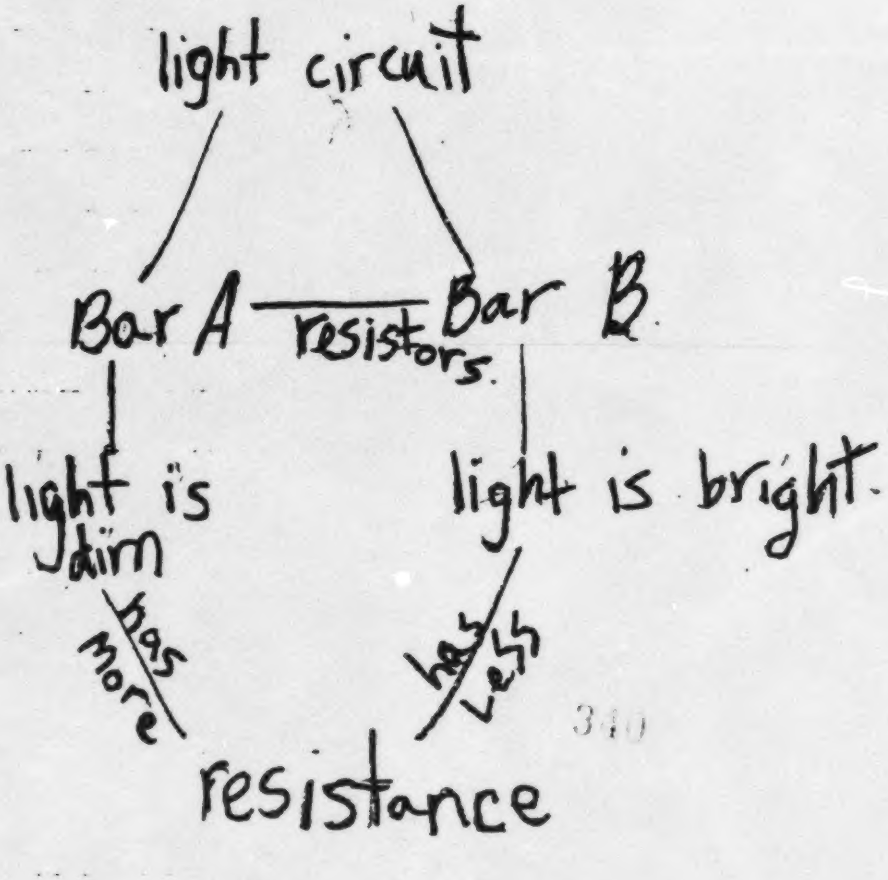

Matter
in shape of
A bottle
has its
temperature
is decreased
thereby
contracts the gases volume
and
slows the
molecules' kinectic energy
heat is applied to the sealed container
then
pressure is increased
kinectic energy is increased
then molecules' move faster
volume of gas is increased (expansion)
then
the bottles seal is broken

Student Number 157, Vestal-8th grade

April, 1980

Student Number - #112 June, 1980 Vestal JHS Eighth Grade

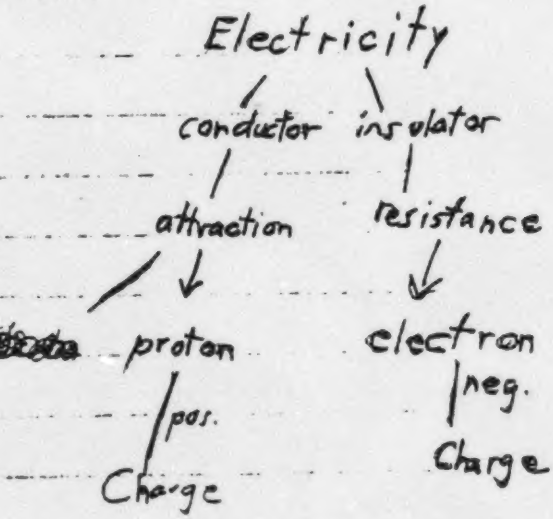
Bar A and bar B are probably resistors. Bar A has a higher resistance because the light is dimmer which Means that not enough Electrons are flowing through the bar. Bar B has low resistance which lets most of the energy through it. Inside the resistors are materials that will not clear conduct easily or they will slow down the electricity, or resist.


light circuit
Bar A
resistors.
Bar B.
light is dim
light is bright.
has More
has Less
resistance

Student #178 June, 1980 Vestal JHS 8th Grade

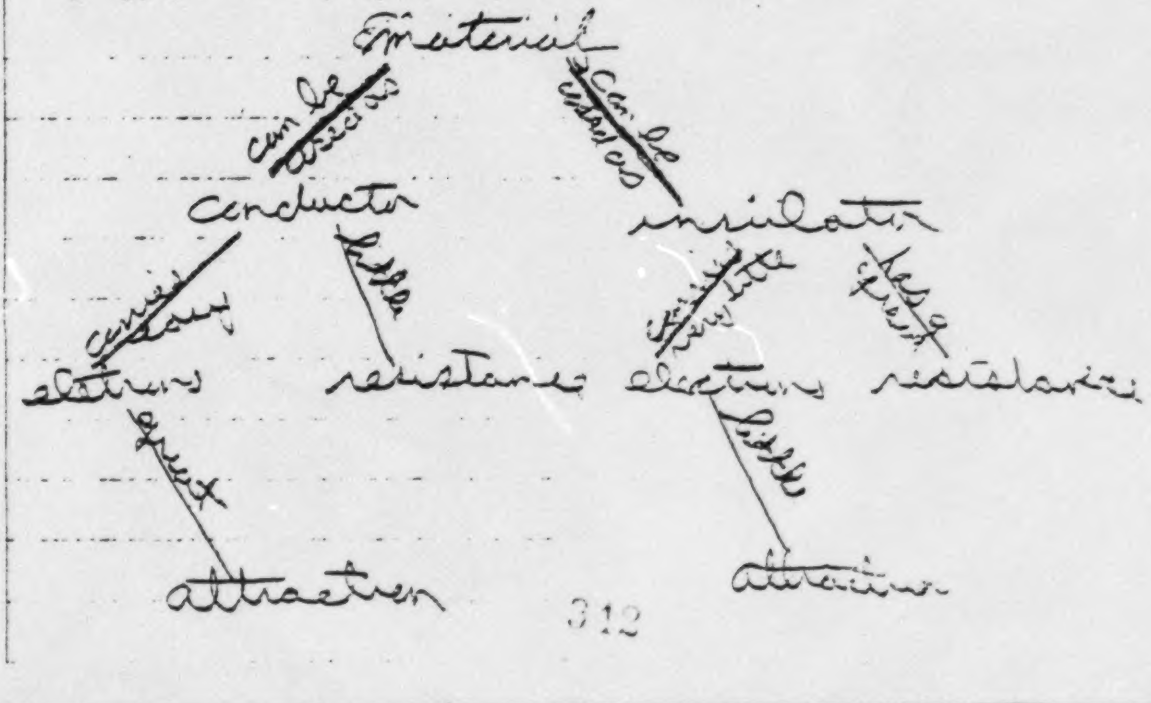
10:00 Bar a causes resitance of electrons
because it is not a good conductor.
Good conductors allow electrons to
pass through easier. Electrons are
pulled by charges on the other side
of the battery these are pos. charges.
They are made by protons. Bar B
is a good conductor and allows
10:04 electrons to pass through easily.

17 3 3E
3A


Electricity
conductor
insulator
attraction
resistance
proton
pos.
Charge
electron
neg.
Charge

Student #114 June, 1980 Vestal JHS 8th Grade

In side Bar A there must be a greater resistance then in Bar B. This means some materials are good conductor such as Bar B some are good unselator such as Bar A. A good conductor carries eletrons easy and offers little resistance. A good insulator carries very little eletrons and has a great resistance. There is a great attraction in Bar B because there is little resistance. There is little attraction in Bar A because theres a great resistance. And that's why I think the [illegible] is greater in Bar B and less in Bar A


Material
can be classed as
can be classed as
conductor
insulator
carries easy
little
carries very little
less great
eletrons
resistance
electrons
resistance
great
little
attraction
attraction